Atmospheric electricity
Radio emissions produced by high altitude discharges above thunderstorms

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Atelier LOFAR
28-29 Mars 2006
Transient Luminous Events and high altitude discharges in the atmosphere

(Elaboration of figure by Lyons et al. 2000)
Map of TLEs by ISUAL

~2000 TLEs observed by ISUAL in 1.5 years

In addition more than 10000 observations at ground

Chen et al., 2005
Conventional theory
penetration of large electric fields in the mesosphere

Predict strong ELF electric fields associated with sprites

Pasko et al, JGR, 1998,
Pasko, Summer school Corté, 2004
Other mechanism: runaway electrons beam accelerated in an avalanche process

- Triggered by cosmic radiation
- High energy electron beam injected in the ionosphere and magnetosphere
- X and gamma emission (Bremsstrahlung) up to 30 MeV

$(Roussel-Dupré \ et \ al, \ 1998)$

Predict strong EM emissions at frequency $\sim 10$-100 MHz

Appear just after conventional breakdown (QS fields or EMP) at the top of the thunderstorm clouds
RHESSI: Maps of Terrestrial Gamma Flashes (TGFs)

498 events in 37 months

Smith et al., 2005

Roussel Dupre et al., 2005

runaway breakdown
EM emissions (ELF, VLF) related with TGFs and TLEs

TGFs

11-28-95, 7:05:29 (3925)

- Sferics related to TGFs – observations at very large distance in Antarctica
- Coming from azimuth toward CGRO footprint
- Thunderstorm detected from CGRO azimuth
  Inan et al., 2005

TLEs

Barrington-Leigh et al., 2001
HF-VHF signals observed by the satellite FORTE

In cloud discharge

Negative initial stroke

Negative dark leader

Positive stroke
**TIPPs : Trans Ionospheric Pulse Pairs (HF-VHF)**

The most intense EM emissions from Earth’s atmosphere (up to 40 db above lightning emissions)

- **Duration**: $0.5 \text{ à } 14 \text{ ns}$ (moy $5 \text{ ns}$)
- **Time between both pulses**: $7.5 \text{ à } 102 \text{ ns}$ (moy $51 \text{ ns}$)
- **Frequency range**: 15 to 150 MHz
- **Dispersion represents the trans-ionospheric propagation**
- **2467 TIPPs**
- **The second pulse is a reflection at the ground**

Jacobson et al., 2003, Tierney et al., 2002

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As HF-VHF emissions are predicted by the runaway relativistic breakdown, are TIPPs produced by sprites?
**Narrow Bipolar Events (NBEs)** are produced by in-cloud (IC) lightning discharges.

Gurevich et al., (2006) observations of bipolar radio waves (0.5 μs) and Extensive Atmospheric Showers- EAS during thunderstorms predict associated giant electron gamma burst resulting of run away breakdown.

**Up to now TIPPs have been only associated with narrow bipolar events**

- **Narrow Positive Bipolar Events**
- **Narrow Negative Bipolar Events**
- **Conventional stroke**

Narrow Bipolar Events (NBEs) are produced by in-cloud (IC) lightning discharges.
Radio signal observed in the 35 – 65 MHz band on 6 antennas of the Nançay station at the time where a burst of extremely high energy cosmic rays was detected. Ravel et al., Nucl. Instr. & Meth. in Phys. Res., 2004.
Perspectives

- LOFAR could provide very important radio wave observations in relation with TLEs and TGFs

- Observations could be correlated with ground based observations
  - previous project: CAL 2003-2006 (Coupling of Atmospheric Layers) coordination of sprite observations in Europe (sprite observations from Pic du midi)
  - next campaigns organized by different institute in Europe

- Observations could be correlated with the microsatellite Taranis (phase A)
  - observations of TLEs, TGFs, high energy electrons, radiowave from DC up to 30MHz (characterization of parent lightnings, whistlers and TIPPs)

- Research of runaway processes in other planets