Review of properties of RHESSI TGFs

Seasonal dependence follows lightning (Smith)

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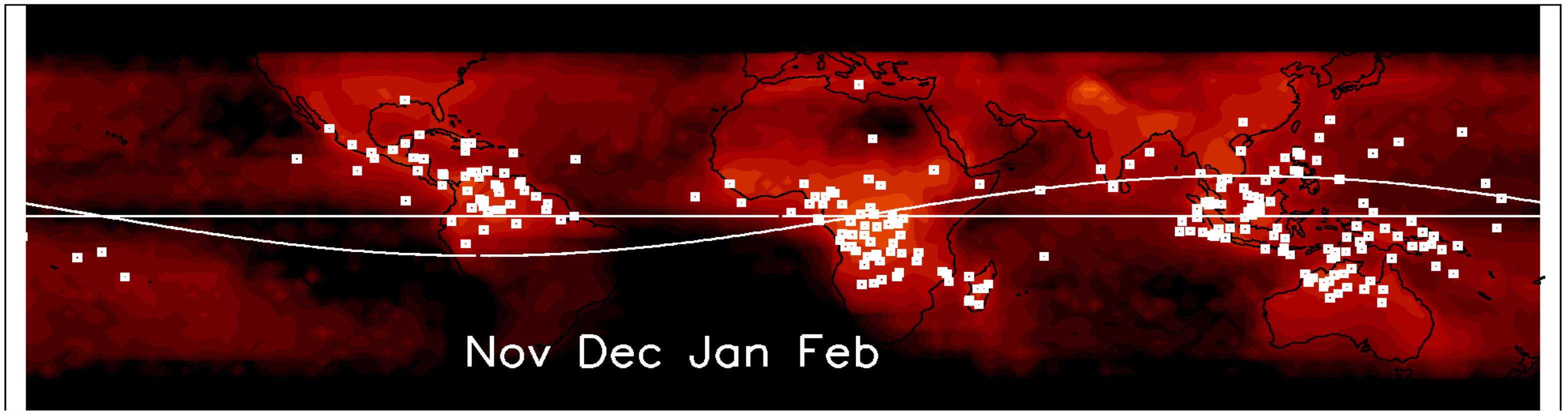
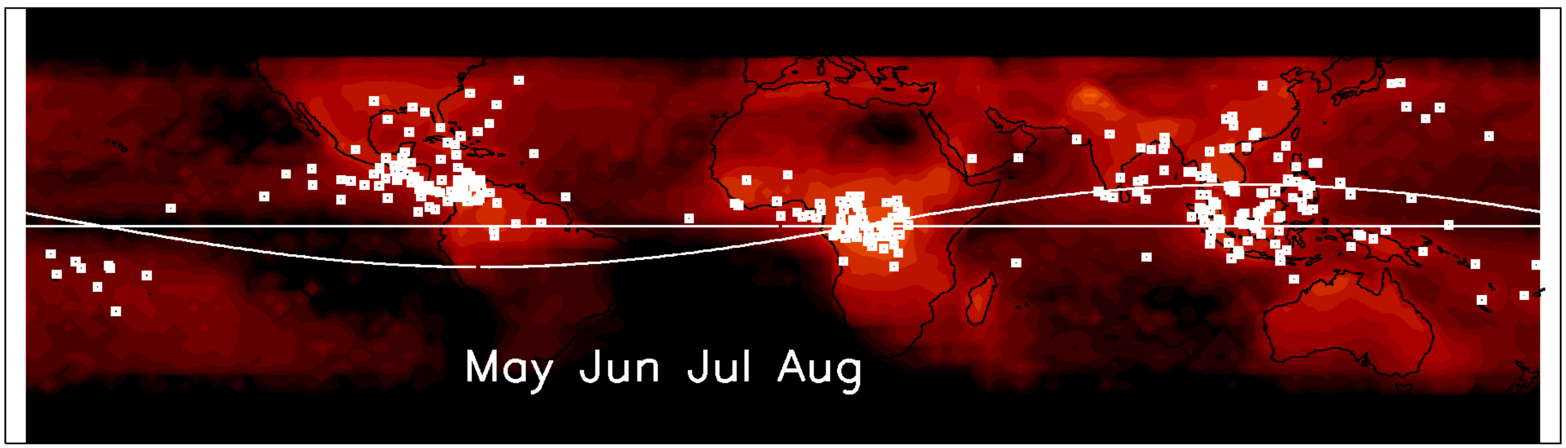
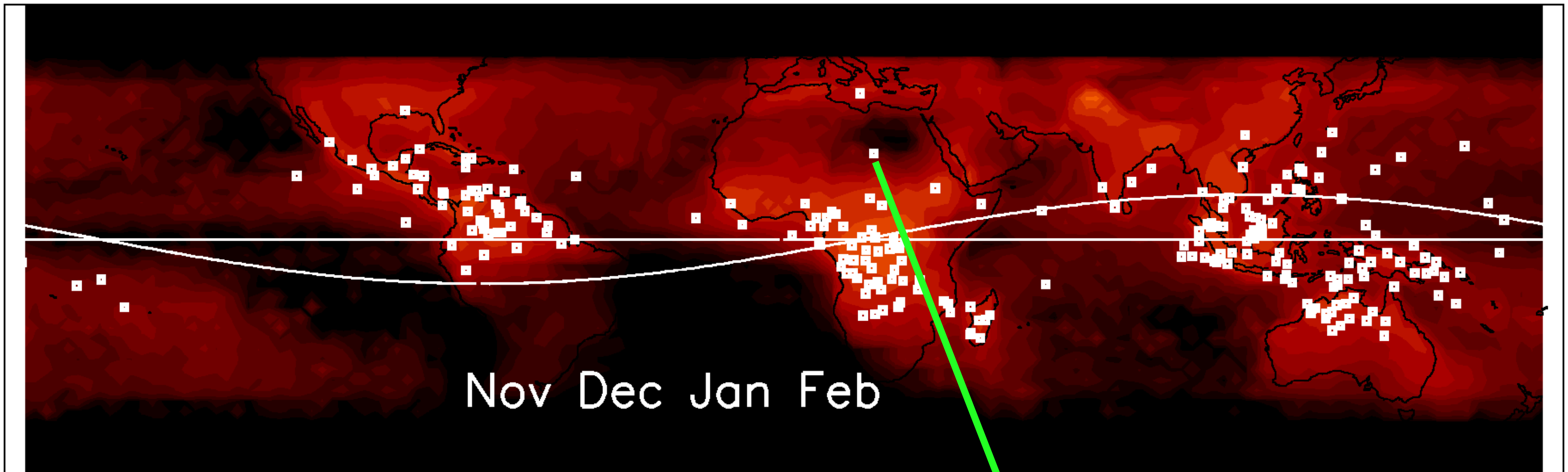
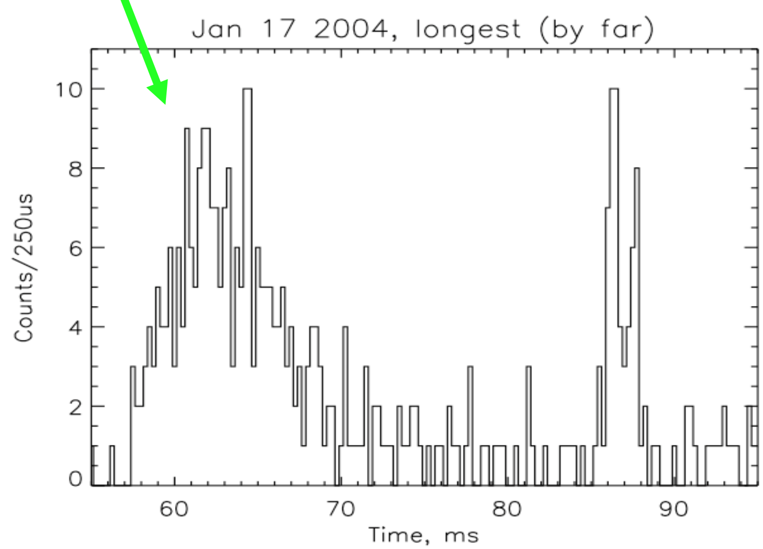




Electron beams in the magnetosphere from TGFs



Brightest, longest RHESSI TGF is in the Sahara desert!

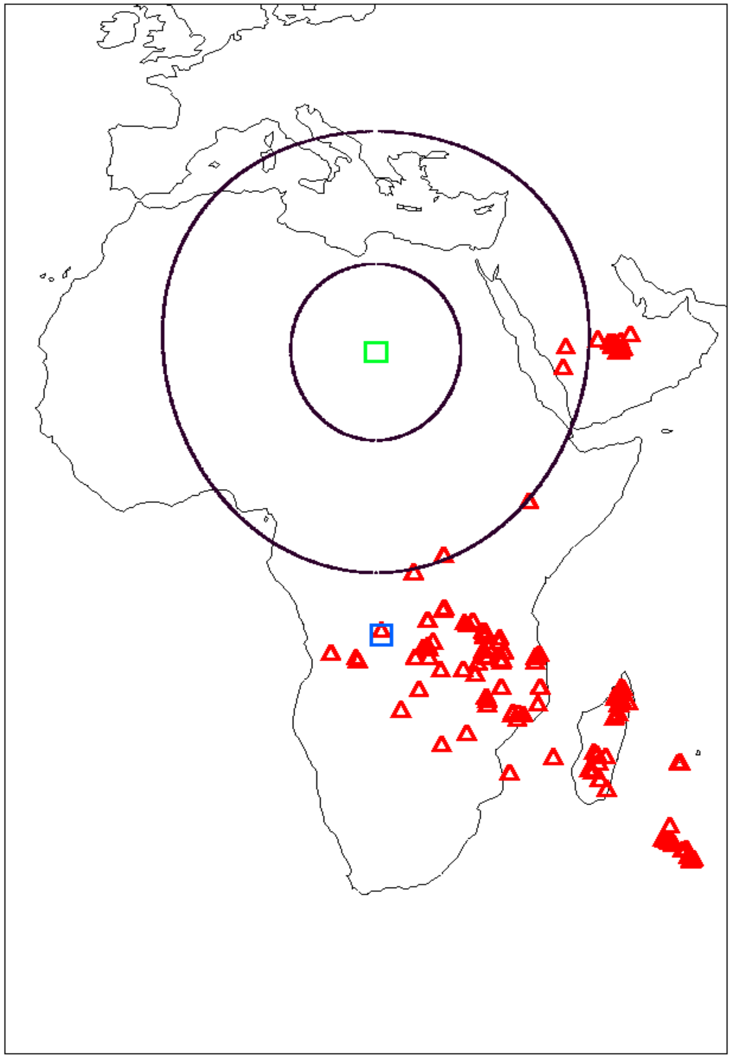


WWLLN sferics show simultaneous thunderstorms at the conjugate point only:

Electron beam?

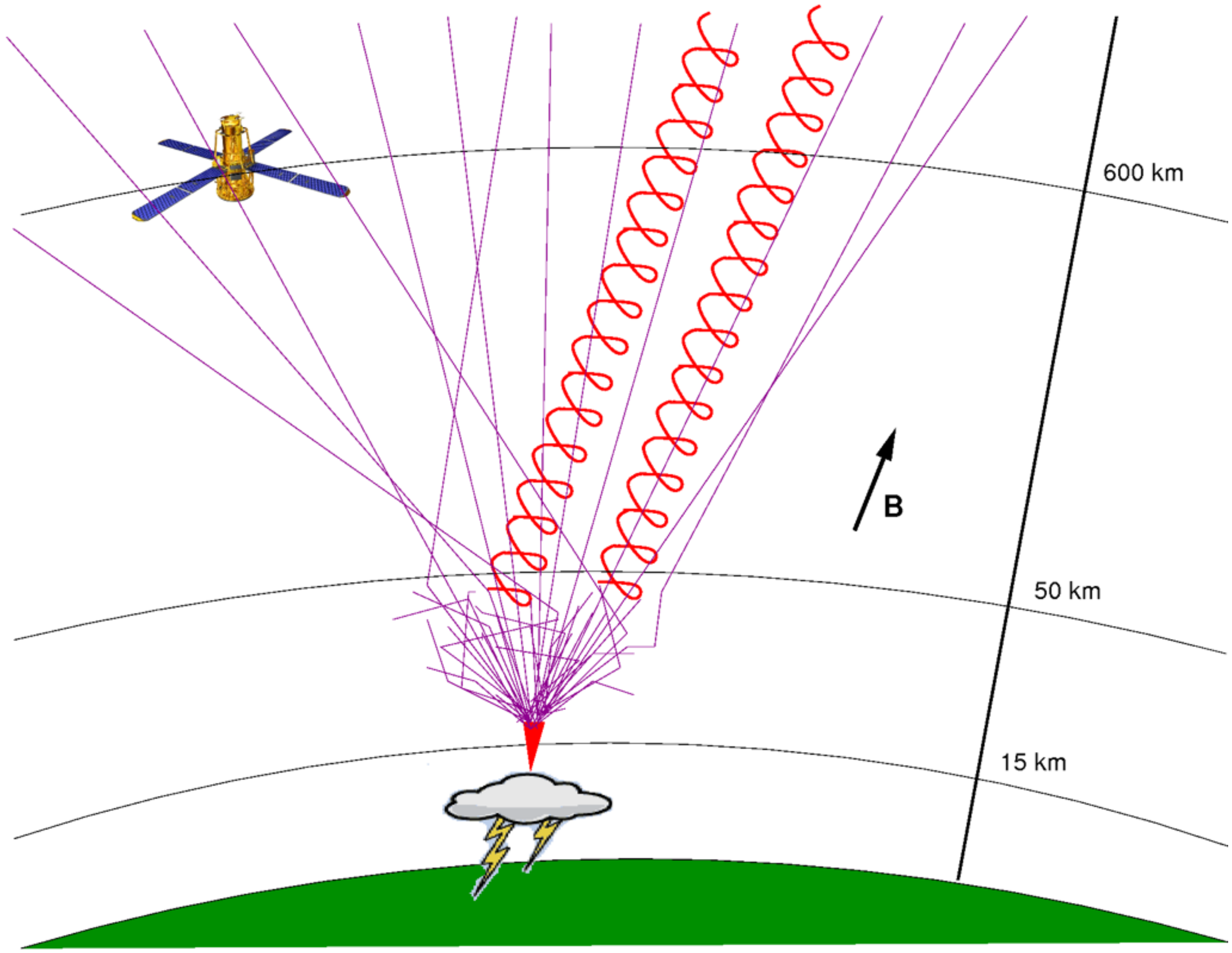
Sferic data courtesy of Erin Lay, U. Washington

Confirmed by METEOSAT images provided by S. Lazarus. Florida Tech.



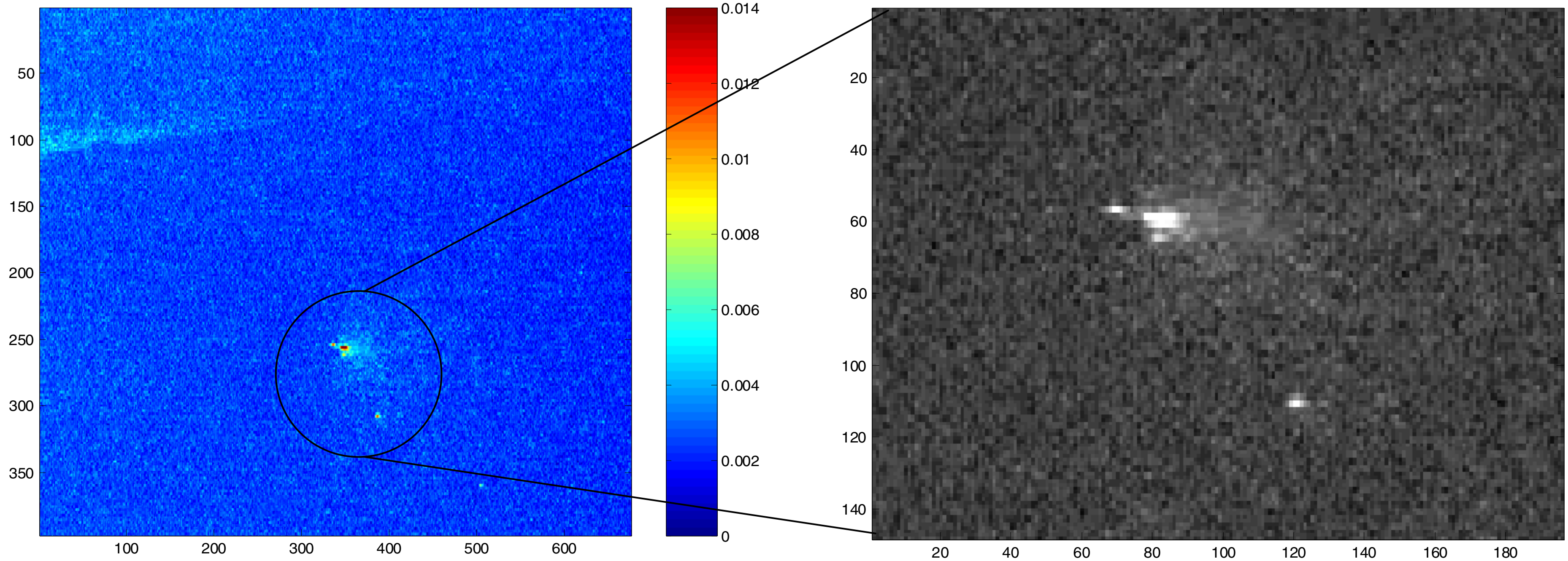
Electron beams in the magnetosphere from TGFs

- A cartoon model (this has to happen whether you see it or not!):



TIGER – Transient Ionospheric Glow Emission in Red

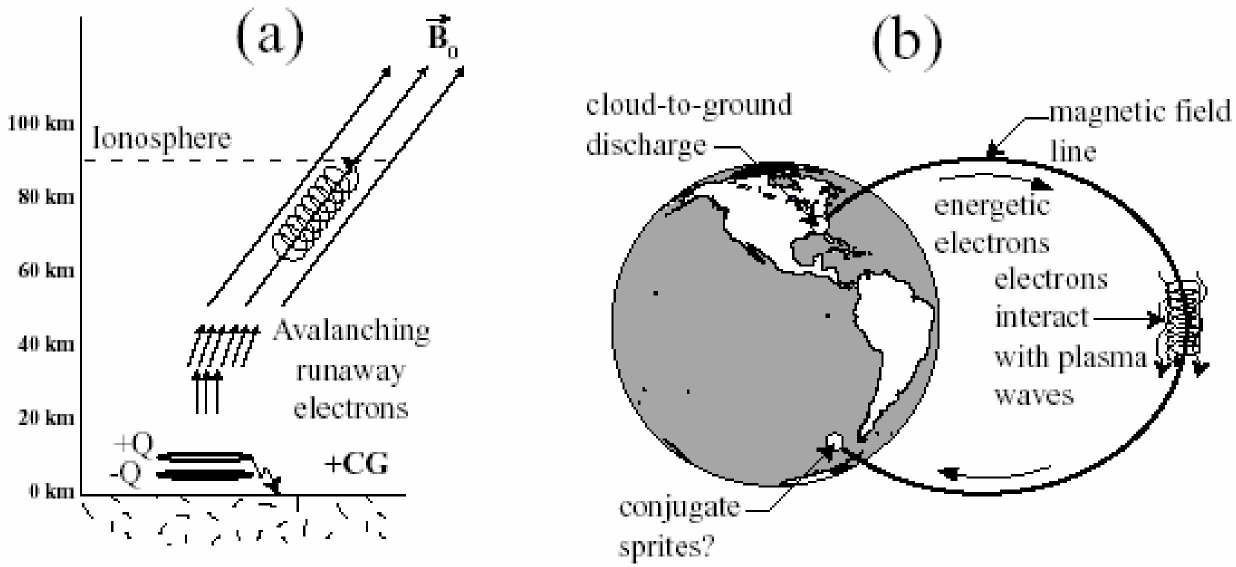
The event was detected above the ocean, range > 1000 km from the nearest visible thunderstorm. A delay > 0.23 seconds from the previous flash.



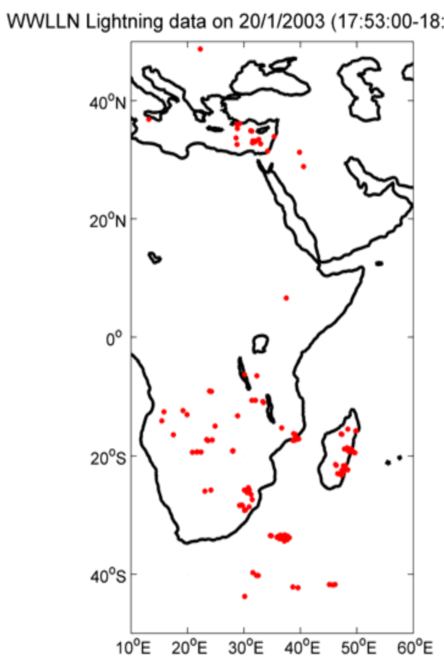
The event appeared in one frame (<33 msec), total luminosity of 312 kR.

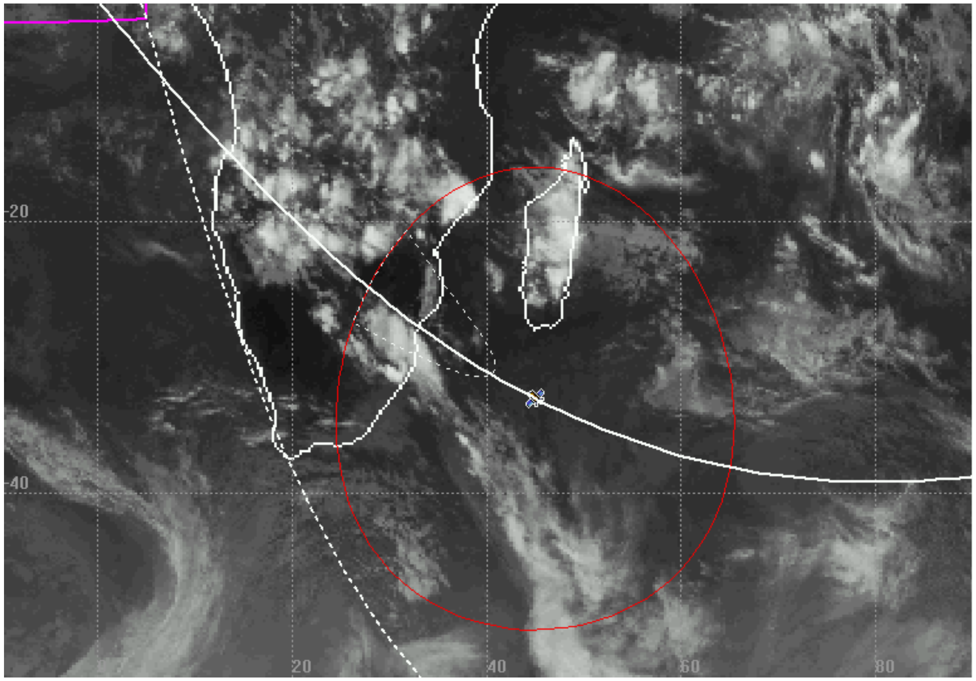
Diffuse shape not similar to known forms of TLEs.

Is the TIGER a Conjugate Event?
[Lehtinen et al., 1999, Marshal et al., 2003]



Thunderstorms at two magnetic conjugate regions (Yair et al., GRL 2005)





The Conjugate region of Madagascar is Turkey.

A lightning occurred at the conjugate point but was –CG : rules out conjugate mechanism (?)

Alternative: lightning Induced Electron Precipitation (LEP).

Ozone layer perturbation due to Blue Jets

Mishin, 1997

Crutzen, 1970

$$NO + O_3 \xrightarrow{1} NO_2 + O_2$$
$$NO_2 + O \xrightarrow{2} NO + O_2$$

•Standard for ordinary lighting with T>1500 K

$K_1 \sim 10^{-12} exp(-1250/\ \ ) \text{ and } K_2 \sim 10^{-11} \text{ cm}^3\text{/s}$

•In discharge in air, energetic electrons should be included.

•Avalanche in the front → Impulse discharge. The pulse duration t_f is ~ the front propagation time→ Negative Streamer parameters.

•The energy dissipated in the front

$$Q_f \simeq \sigma_f \cdot E_c^2 \simeq 5 \cdot \tilde{p}^3 \ \mathrm{kJ/m^3 s}$$

$$(T - T_0)/T_0 \ll 1 \ (T_0 \simeq 250 \ \mathrm{K})$$

•Basic "pumping" processes: Excitation and ionization , attachment, dissociative recombination, and charge exchange.

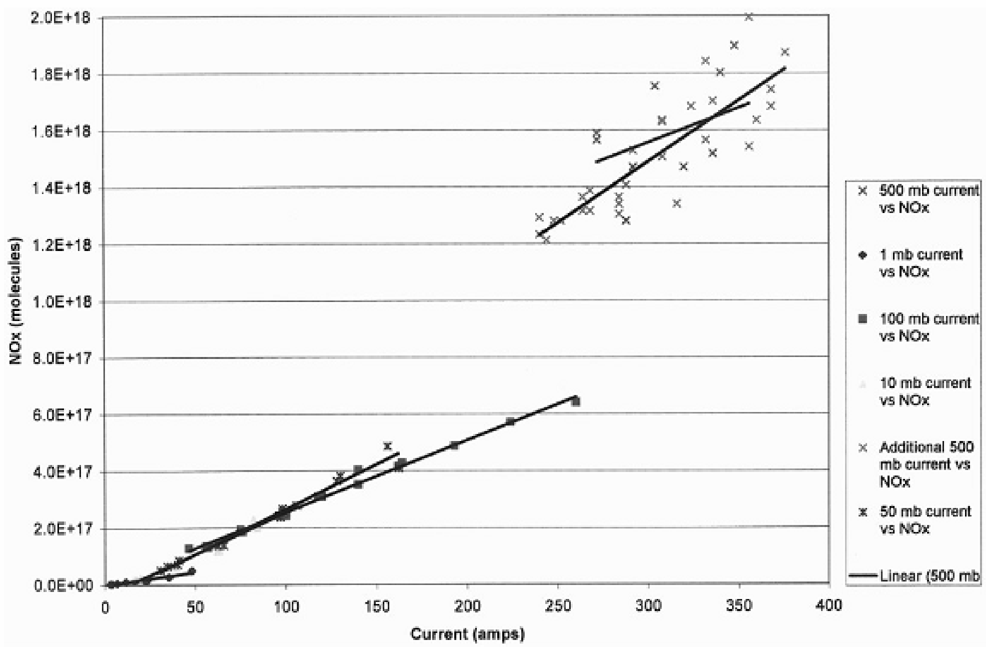
$$N_2 + e \rightarrow \begin{cases} N + N + e & (k_N) \\ N^+ + N' + 2e & (k'_N) \\ N_2^\# + e & (k_N^\#) \end{cases}$$

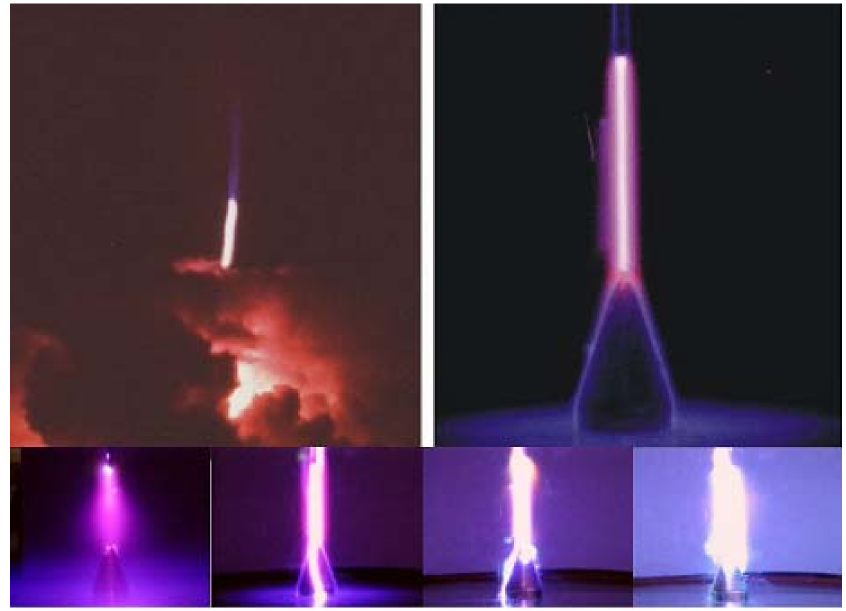
$$O_2 + e \rightarrow \begin{cases} O + O + e & (k_O) \\ O_2^\# + e & (k_O^\#) \end{cases}$$

Simplified set of

Reaction	*Rate constant*
$\begin{pmatrix} N \\ N' \end{pmatrix} + O_2 \underset{(+)}{\longrightarrow} NO + O$	$10^{-10.8} e^{-3600/T}$ $6 \cdot 10^{-12}$
$\begin{pmatrix} N \\ N' \end{pmatrix} + NO \underset{(-)}{\longrightarrow} N_2 + O$	$10^{-9.8} e^{-460/T}$ $7 \cdot 10^{-11}$
$N + O + N_2 \longrightarrow NO + N_2$	$1.8 \cdot 10^{-31} T^{-0.5}$
$N_2^{\#} + \begin{pmatrix} O \\ O_2 \end{pmatrix} \longrightarrow \begin{pmatrix} NO + N' \\ N_2 + O \\ N_2 + 2O \end{pmatrix}$	$1.5 \cdot 10^{-11}$ $0.6 \cdot 10^{-11}$ $2.5 \cdot 10^{-12}$
$NO + \begin{pmatrix} N_2^+ \\ O_2^+ \\ e \end{pmatrix} \longrightarrow NO^+ + \begin{pmatrix} N_2 \\ O_2 \\ 2e \end{pmatrix}$	$3.3 \cdot 10^{-10}$ $4.4 \cdot 10^{-10}$ $10^{-6.1-13.8/\theta}$
$N + NO_2 \longrightarrow \begin{pmatrix} N_2 + O_2 \\ N_2O + O \\ N_2 + 2O \\ NO + NO \end{pmatrix}$	$7.0 \cdot 10^{-13}$ $3.0 \cdot 10^{-12}$ $9.1 \cdot 10^{-13}$ $2.3 \cdot 10^{-12}$
$O_3 + O \longrightarrow O_2 + O_2$	$10^{-11} e^{-2150/T}$
$O + O_2 + M \longrightarrow O_3 + M$	$6.2 \cdot 10^{-34}$
$O_2^- + \begin{pmatrix} N \\ N_2^{\#} \\ O_2^{\#} \end{pmatrix} \longrightarrow e + \begin{pmatrix} NO_2 \\ O_2 + N_2 \\ O_2 + O_2 \end{pmatrix}$	$5 \cdot 10^{-10}$ $2 \cdot 10^{-9}$ $2 \cdot 10^{-10}$
$O_2^+ + \begin{pmatrix} N \\ N_2 \end{pmatrix} \longrightarrow NO^+ + \begin{pmatrix} O \\ NO \end{pmatrix}$	10^{-10} 10^{-17}
$N_2^+ + \begin{pmatrix} O \\ O_2 \end{pmatrix} \longrightarrow \begin{pmatrix} NO^+ + N' \\ O_2^+ + N_2 \end{pmatrix}$	$1.4 \cdot 10^{-10}$ $6 \cdot 10^{-11}$
$O_2^{\#} + \begin{pmatrix} N_2 \\ O_2 \end{pmatrix} \longrightarrow \begin{pmatrix} O_2 + N_2 \\ O_2 + O_2 \end{pmatrix}$	$2 \cdot 10^{-20}$ $2.4 \cdot 10^{-18}$
$e + O_2 + \begin{pmatrix} O_2 \\ N_2 \end{pmatrix} \longrightarrow O_2^- + \begin{pmatrix} O_2 \\ N_2 \end{pmatrix}$	$(4.7 - \frac{\theta}{4}) 10^{-31}$
$e + O_2 \longrightarrow O^- + O$	$10^{-9.3-12.3/\theta}$
$O_2^- + O \longrightarrow O_3 + e$	$1.5 \cdot 10^{-10}$
$O_3 + e \longrightarrow \begin{pmatrix} O_2 + O + e \\ O_2^- + O \end{pmatrix}$	$10^{-8-5.2/\theta}$ 10^{-9}

Laboratory simulations of jets

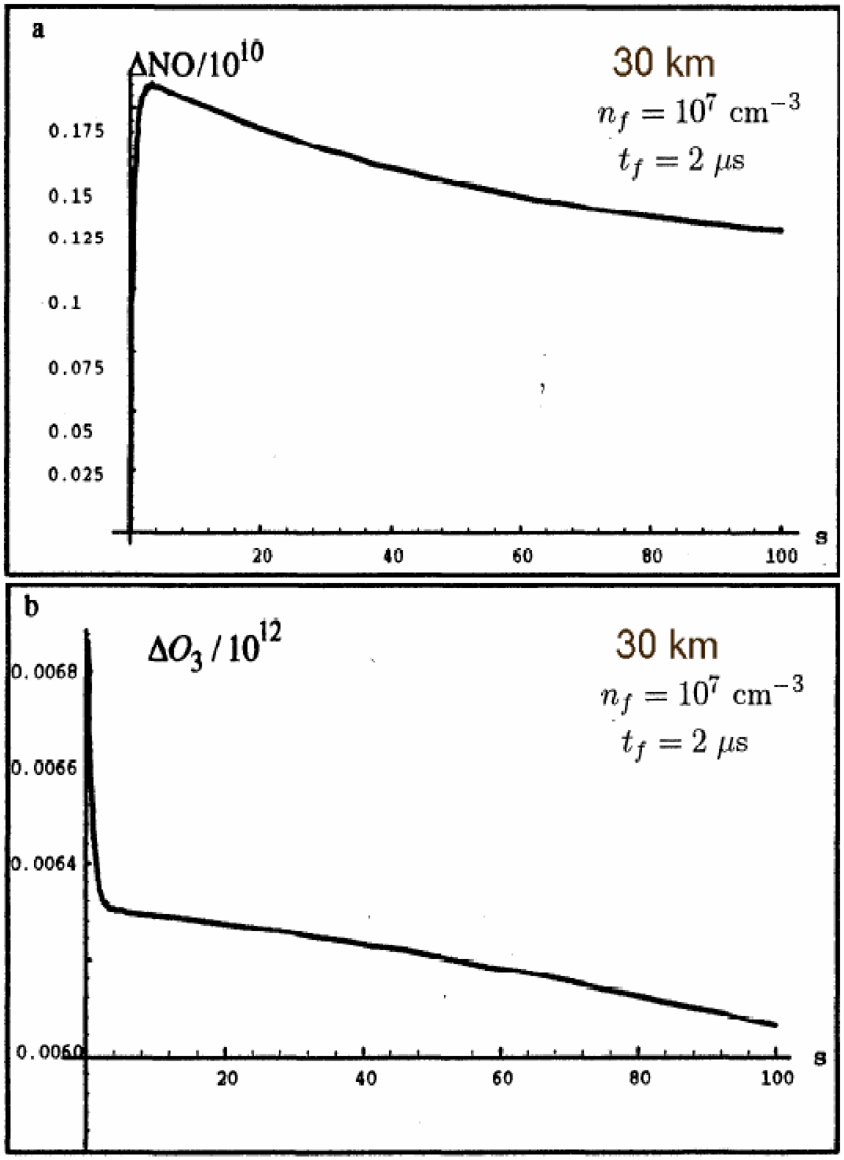


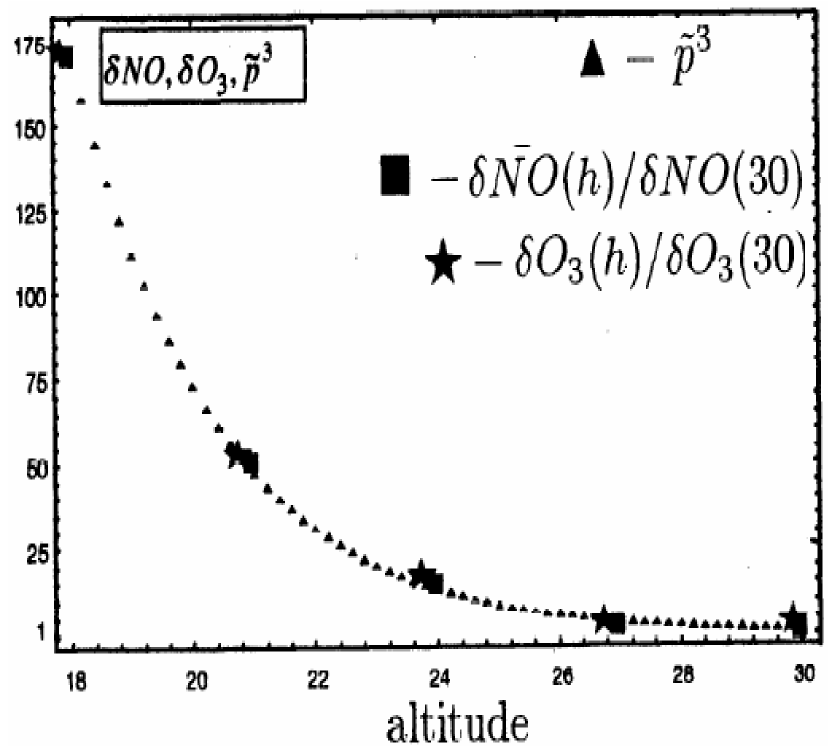


1 mb 10 mb 50 mb 100 mb

Ozone perturbation

Numerical simulations were performed with a number of the initial conditions typical for the "average" ozone layer. At the maximum of the layer, $h \simeq 30$ km, we have chosen $[O_3]_0 = (0.8\text{–}1)\cdot 10^{12}\ \mathrm{cm}^{-3}$, $[NO]_0 = 10^{-2}\cdot[O_3]_0$





Perturbations will be much stronger in the bi-leader approach.

Effects of TLEs on the Atmosphere

Sprites

- negate part of the lightning dynamo effect of the global circuit
- emit significant 1NN_2^+ emission ➔ ionization in sprites
- transfer 1 ~ 10 MJ of energy from troposphere to upper atmosphere
- chemical effects?

Elves

- emit significant 1NN_2^+ emission ➔ ionization in elves
- TOE contain could increase by 50%
- could disturb radio communication?
- transfer 0.1 ~ 1 MJ of energy from troposphere to ionosphere

Summary

- Satellite derived global TLE rates
  - ➢ Elve: ~3.2 events/minute
  - ➢ Sprite: ~0.5 events/minute
- The real occurrence rate of elves could be an order higher; the real occurrence rate of sprites may be close to ISUAL derived value or differs by less than a factor of two.
- Elves are the most abundant type of TLEs; with sprite & halo as the distant second.
- Distribution of sprites follows that of the lightning, whereas elves congregate preferentially over the oceans.
- With these TLE rates, the impacts/effects of TLEs on the Earth's environment could be determined with confidence.