Lightning activity

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IHY Workshop on
Advancing VLF through the Global AWESOME Network
Basic lightning physics

- Charge builds up inside thundercloud, reaches breakdown threshold (~300 kV/m)
Basic lightning physics

- Preliminary breakdown within cloud

$t=1 \text{ ms}$
Basic lightning physics

- Propagating “Stepped leader” forms ~30 µs after electric field exceeds breakdown fields of air

\[ t \sim 1.1 \text{ ms} \]
\[ v \sim 200 \text{ m/ms} \]
Basic lightning physics

- “Stepped leader” propagates down one “step” at a time, pauses (10s of μs), might split into pieces

I~1kA

~50m

t~20 ms
Basic lightning physics

- Ground electrified as stepped leader approaches

$t \approx 25 \text{ ms}$
Basic lightning physics

- Ionized (~10,000 K) plasma streamers rise from ground (often from high points like treetops, poles, etc) to meet leader

$\text{t} \sim 30 \text{ ms}$
Basic lightning physics

- Leaders and some streamers connect

Attachment process

$t \approx 35$ ms
Basic lightning physics

- Channel formed: high current flows at bottom of channel, beginning “return stroke”

$\text{t} \sim 35 \text{ ms}$

$I \sim 10\text{s of kA}$
Basic lightning physics

- Return stroke propagates upward, comparable to speed of light
- 30,000 K temperatures

$\text{v} \approx 0.4c$

$t \approx 35 \text{ ms}$
Basic lightning physics

- Return stroke reaches cloud
- Occurs much faster than stepped leader

$t \approx 35 \text{ ms}$
Basic lightning physics

- Return stroke weakens as charge is depleted
- Total charge transfer typically in 1s of C

$t \sim 36$ ms
Basic lightning physics

- Often several return strokes ~50 ms apart
- Typically weaker than first return stroke

$\text{t} \sim 90 \text{ ms}$

$I \sim 10 \text{ kA}$
Basic lightning physics

- Weaker “continuing currents” may continue for 100ms or more, transferring more charge. Sprites may be triggered at 10s of C transferred.
Types of lightning

- **IC (Intracloud)**
  - Flash occurs within cloud
  - Accounts for most of lightning activity

- **–CG (Cloud-to-ground)**
  - Cloud lowers negative charge to ground
  - More common CG type

- **+CG**
  - Cloud lowers + charge
  - Linked to most sprites
  - Often only 1 return stroke
Lightning Statistics

- In-Cloud (IC) 75% of total
- Cloud-to-Ground (CG) 25%
- IC may be intracloud, cloud-to-cloud, or cloud-to-sky

- Of CG, >90% are -CG
- Typical CG currents 1–200 kA
- CG charge removal of
  - 1–40 C (-CG),
  - 20–350 C (+CG)
- Energy up to 10 GJ, power
Global occurrence rates

~ 2000 active thunderstorms
40-50 flashes per second

Christian et al., 2003
Spatial variations

Christian et al., 2003
Seasonal variations

Christian et al., 2003
Seasonal variations

- Movie HRAC_Globe.mov (need Quicktime)
United States Flash Rate

1996 - 2005 Flash Density Map
10 kilometer grid
IC and CG ratios

Boccippio et al., 2001
Large +CG

NLDN % + CG

NLDN +CG > 75 kA [10^{-3} fl/km^2/yr]  Boccippio et al., 2001
Available lightning data

- **Satellites**
  - NASA's Lightning Imaging Sensor (LIS), Optical Transient Detector (OTD)
    - [http://thunder.msfc.nasa.gov/data/lisbrowse.html](http://thunder.msfc.nasa.gov/data/lisbrowse.html)
    - Data available from twice-per-day passes

- **Ground networks**
  - METEORAGE – lightning over Europe
  - Your AWESOME receiver
Broadband data and the “SPH” Channel