Lightning and Its Impacts

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Lightning

- **Temperature**
  50,000 degrees F

- **Intensity**
  200,000,000 Volts or more
  25,000 Amperes

- **Size**
  One inch in diameter

- **Velocity**
  One third the speed of light
Fulgurites
Fulgurites - Egypt

Carion Mineraux, Paris
Successful connection with object on ground

Downward leaders

Hugo Binz, 1967
Mt. San Salvatore
Lugano, Switzerland
Three Upward Flashes from communications towers
Lightning

- A cloud-to-ground (CG) lightning flash contains one or more return strokes

- Cloud lightning precedes CG lightning in ~70% of all thunderstorms

- Cloud flash rates are 3 to 5 times more than CG flash rates
Cloud-to-ground (CG) flashes and strokes

Negative CG flashes usually produce 3-4 return strokes.

Left flash - 3 return strokes resolved in time by moving the camera rapidly back and forth.

Photo © Ronald Holle 2005
Cloud lightning

Spider flash – up to 120 miles long
Impacts of lightning

- 24,000 deaths and 240,000 injuries a year worldwide
- Half of all western US forest fires
- 300,000 insurance claims for homes damaged by lightning per year in US
- Several billion dollars in damages and avoidance costs per year in US
Polarity of lightning

- 90 to 95% of cloud-to-ground lightning lowers negative charge to ground
- 5 to 10% of cloud-to-ground lightning lowers positive charge to ground
- Half of all positives have Long Continuing Current (LCC); 10% of negatives have LCC
- Every cloud-to-ground flash is fully capable of causing death and significant damage
Outline

- Lightning
- Lightning climatologies
- Lightning detection
- Lightning safety
U.S. flash density – Annual
Monthly flash variation – U.S.
June NLDN cloud-to-ground flash density

2004-2008
July NLDN cloud-to-ground flash density

2004-2008
August NLDN cloud-to-ground flash density

2004-2008
10am to noon NLDN cloud-to-ground flash density

2006 - 2010 Flash Data
20 km density grid
10:00 - 12:00 Local Time
6,640,541 flashes

2006-2010
Noon to 2pm NLDN cloud-to-ground flash density

2006 - 2010 Flash Data
20 km density grid
12:00 - 14:00 Local Time
13,472,561 flashes

2006-2010
Midnight to 2am NLDN cloud-to-ground flash density

2006 - 2010 Flash Data
20 km density grid
00:00 - 02:00 Local Time
9,247,847 flashes

2006-2010
Outline

- Lightning
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Existing applications of lightning data

- Airport, rocket launch, and industry operations
- Climatologies
- Recreation safety
- Fire weather
- Complement/substitute radar
- Severe and winter weather
- Defense
- Convective rainfall estimation
- Assimilation into numerical weather prediction models
- NOx
Uses of CG data

- Direct indication of lightning threat
- Covariate with other data (radar, rainfall…)
- Substitute for missing data (radar, satellite…)
- Proxy for other meteorological data (LWC, graupel…)
Two categories of lightning

Cloud-to-ground (CG)

Cloud
Time-of-arrival (TOA) location

1. Lightning contacts ground
2. Low frequency signals propagate in all directions
   - Equal time difference between sensors 1 and 2
   - Equal time difference between sensors 1 and 3
   - Equal time difference between sensors 2 and 3
3. Intersection of 3 or more hyperbolas is stroke location
Direction finding

1. Lightning emission occurs
2. Signals propagate in all directions
3. Sensors 1, 2 and 3 determine direction of source
4. Central processor triangulates results from each sensor
5. Optimization algorithm picks the location with the smallest angle error for all sensors
Both TOA and direction finding

5 sensors in Florida
24 hours of GLD360 data

Ending 2100 UTC 21 June 2011 - 2,399,593 strokes
Cloud lightning
VHF total lightning mapping network
Long VHF mapped cloud flash and four CGs

Length of cloud flash: 60 miles
Duration: 2 seconds
Outline

- Lightning
- Lightning climatologies
- Lightning detection
- Lightning safety
Two safe places – the only places

Lightning safety recommendations identify two reliable safe places:

1. Inside a large substantial frequently-occupied building

2. Inside a fully-enclosed metal-topped vehicle
### Five lightning safety myths

1. Lightning is attracted to metal  **False**
2. Direct strike is the most common casualty  **False**
3. Precautions taken outside will always be safe  **False**
4. If I’m out of the rain, I’m safe  **False**
5. Rubber tires provide protection  **False**
Lightning safety

- **Certain safety:**
  -- Inside a large substantial frequently-occupied building
  -- Inside a fully-enclosed metal-topped vehicle

- **Not certain safety:**
  -- What a person wears or carries
  -- Where or how a person stands
  -- On what a person stands
  -- Anywhere outside
Fatalities by state - multiply by 10 for injuries

Source: Storm Data
Alaska: 0  Hawaii: 0
American Somoa: 1
D.C.: 0  Guam: 1
Puerto Rico: 3  Virgin Islands: 1

2001-2010
Fatality rate by state

Source: Storm Data
Ranks include 50 states, D.C., and Puerto Rico

2001-2010
Annual U.S. lightning fatalities since 1900

Reported fatalities

Population-weighted U.S. lightning fatalities

- **Deaths per million**
- **% rural**

Graph showing the decrease in lightning fatalities per million and the percentage of rural population from 1900 to 2000.
Types of U.S. lightning fatalities 100 years apart

1990s

Agriculture

Indoors

Outdoors

Recreation

Small structures

Sports

1890s

0 25% 50% 75% 100%
Cloud-to-ground flash

Unsuccessful downward leaders

Preferred strike points
- Tall
- Isolated
- Pointed

Upward leader

Photo © 1984 by Johnny Autery
Lightning striking parking lot between poles
Iowa mail box
www.lightningsafety.noaa.gov

- Dr. Mary Ann Cooper, Mr. William Roeder (NASA-KSC), Mr. John Jensenius (NWS, Gray, Maine), and others have collaborated on this site since 2001

- This is the most complete and accurate web site on lightning safety in the world

- Lightning Safety Awareness Week – last full week in June
Activity of lightning fatalities in *Storm Data*, 2006-10

-Courtesy John Jensenius, NWS-
Location of lightning fatalities in *Storm Data*, 2006-10

- Under tree/tree in yard
- Open/open field/sports field
- Yard outside home
- Water
- Road/vehicle
- Boat/barge

*Courtesy John Jensenius, NWS*
Medical impacts on lightning victims

- Death is due to cardiopulmonary arrest
- Serious injuries are mainly neurological
  -- Damage to brain and spinal column
  -- Significant problems in task ordering
  -- Seizures
  -- Can have catastrophic work and personal impacts
  -- Lack of understanding in medical community
  -- Major deterioration from prior personality
  -- Isolation and depression
  -- Impacts often grow worse as years pass

Male percentage

- An average of 80% of lightning deaths and injuries are to males
- Worldwide, for many decades
- Most often, these are young adults
Mechanisms of lightning injury

- Direct strike - 3 to 5%
- Contact injury - 3 to 5%
- Side flash - 30 to 35%
- Ground current - 50 to 55%
- Upward leader - 10 to 15%
- *Blunt injury – unknown*

--Direct strike is a very uncommon mechanism
--Lightning safety is not about the direct strike

(Cooper and Holle, 2010)
1. **Direct strike – 3 to 5%**
2. Contact voltage – 3 to 5%
3. Side flash – 30 to 35%
4. Ground current/step voltage – 50 to 55%
5. Upward leader – 10 to 15%
CG flash sequence in Colorado storm

- Successive flashes were within 9.3 miles/15 km and 5 minutes of previous CG
- Thousands of CG pairs
- 80% of successive flashes were within 6 miles
30-30 rule and ‘When Thunder Roars’

• The 30-30 rule was developed in 1998 based on this figure

• First 30
  Count the seconds from ‘flash to bang’ = 30 seconds.
  At 5 seconds per mile = 6 miles

• Second 30
  Wait time in minutes after last lightning and thunder

• Since then, a simplified rule for the start of a lightning event is “When Thunder Roars, Go Indoors”

• For objective rules, use lightning data rather than variable thunder sound

• Lightning data show 8 to 10 miles is best

• 30 minutes - depends on length of evacuation time – the larger the event, the longer the time
Safe structures

- Large substantial building
- Where people frequently live or work
- Has grounded wiring and plumbing, and metal structural members
- Follows building codes
- Surrounds people inside with a Faraday cage-like effect
Lightning casualties in vehicles

Direct strikes to fully-enclosed metal-topped vehicles

- People described themselves as *uninjured* in more than half of events
- Tires may flatten when current flows around car, then to ground through axles and tires
- A safe place from the danger of lightning compared to remaining outside
U.S. fatalities in dwellings

- 21 events, 31 deaths, 4 injuries known since 1992
- Mostly from homes catching fire after lightning strike at night
- Nearly all fatalities due to dwelling fires involve elderly, young, or physically or mentally disabled people
Non-U.S. fatalities in dwellings

<table>
<thead>
<tr>
<th>Type</th>
<th>Events</th>
<th>Deaths</th>
<th>Injuries</th>
</tr>
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<tbody>
<tr>
<td>Inside</td>
<td>53</td>
<td>106</td>
<td>63</td>
</tr>
<tr>
<td>Huts</td>
<td>25</td>
<td>76</td>
<td>68</td>
</tr>
<tr>
<td>On property</td>
<td>13</td>
<td>17</td>
<td>4</td>
</tr>
</tbody>
</table>

- Nipa Hut-Philippines
- Hut-Africa
- Rondavels-S. Africa
Completely unsafe structures - 1

Unsafe - has the word ‘shelter’ attached – sun, beach, golf, picnic, or rain shelter
Completely unsafe structures - 2

- **Baseball dugout**
  - Open side
  - Small
  - No conducting material around people inside
  - Nearby tall utility pole
  - Water on ground

- **Tents**
  - No safety from lightning
## Non-U.S. schools

<table>
<thead>
<tr>
<th>Location/activity</th>
<th>Events</th>
<th>Deaths</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside</td>
<td>15</td>
<td>31</td>
<td>208</td>
</tr>
<tr>
<td>On property</td>
<td>11</td>
<td>29</td>
<td>82</td>
</tr>
<tr>
<td>School building struck</td>
<td>4</td>
<td>19</td>
<td>88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>79</td>
<td>378</td>
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</table>
Safety recommendations - buildings

U.S.
• No deaths inside substantial buildings
• Many casualties in small structures for rain protection
• Emphasize going indoors

Non-U.S.
• Many deaths in schools and small structures
• Go into fully-enclosed metal-topped vehicle if available
• Add as much lightning protection as possible
Global lightning fatalities

- For the lack of better information, estimate 6 deaths per million per year
- Apply this rate to 4 billion people
- Resulting estimate is 24,000 deaths and 240,000 injuries per year globally
- Another recent global estimate is 8,000 deaths/year
- Lightning fatality data over long periods is needed on a national basis in the most affected countries (Malawi-84/million/year)
Lightning protection

Air terminals – Lightning rods/conductors
Lightning protection of buildings

- Lightning rods do not stop lightning from striking a building
- Rods control the strike and take the current surge through a very thick metal cable into the ground
- Use a bonded, insured, and experienced lightning protection specialist
- Lightning rods are on power poles, police and fire stations, airports, schools, hospitals - anywhere a strike is highly undesirable
Lightning protection

Rods on towers

Catenary wires

Kennedy Space Center
The End

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