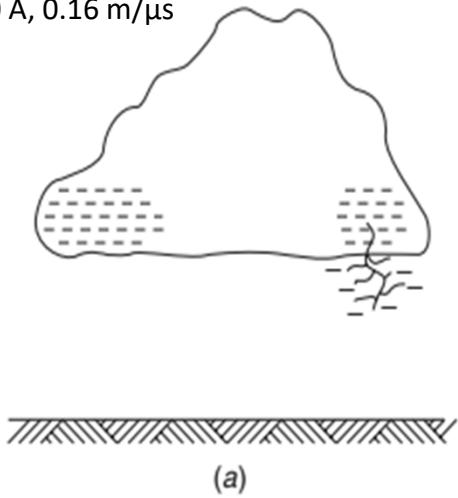
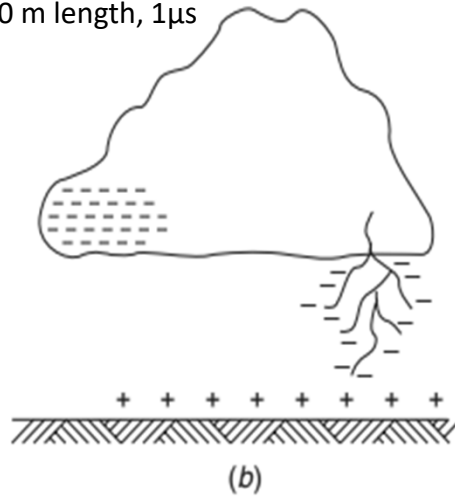


# Mechanisms of Lightning strokes

Pilot Streamer:  
100 A, 0.16 m/ $\mu$ s

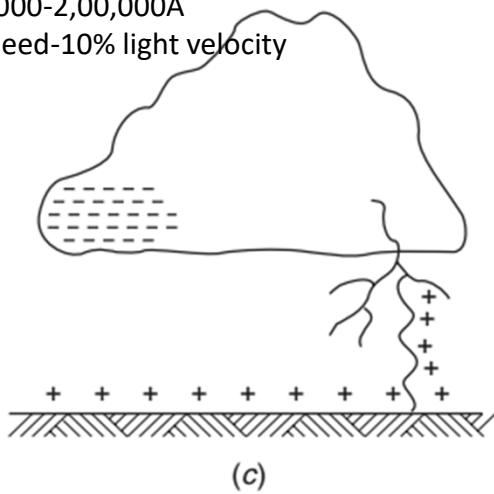


Stepped Leader:  
50 m length, 1 $\mu$ s

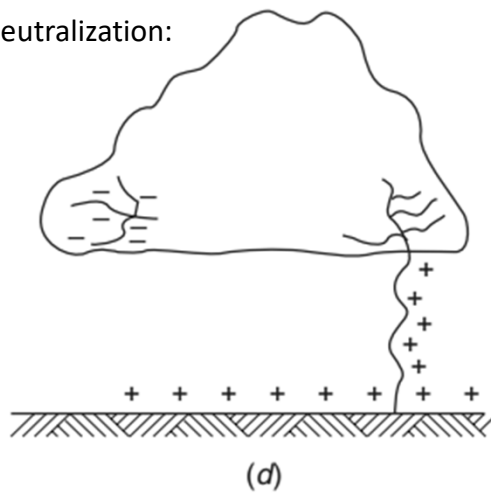


# Mechanisms of Lightning strokes

Return Streamer:  
1,000-2,00,000A  
Speed-10% light velocity

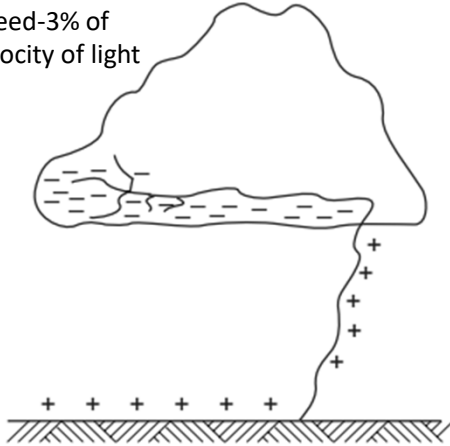


Neutralization:



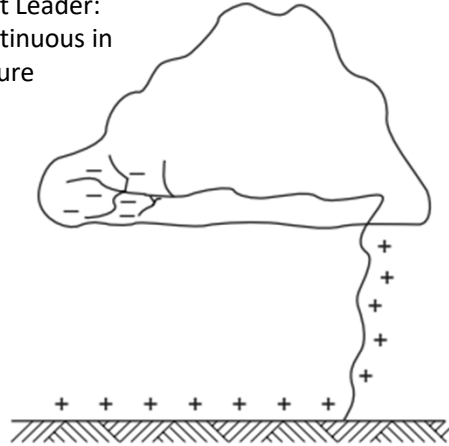
## Mechanisms of Lightning strokes

Dart Leader:  
Speed-3% of  
velocity of light



(e)

Dart Leader:  
continuous in  
nature



(f)

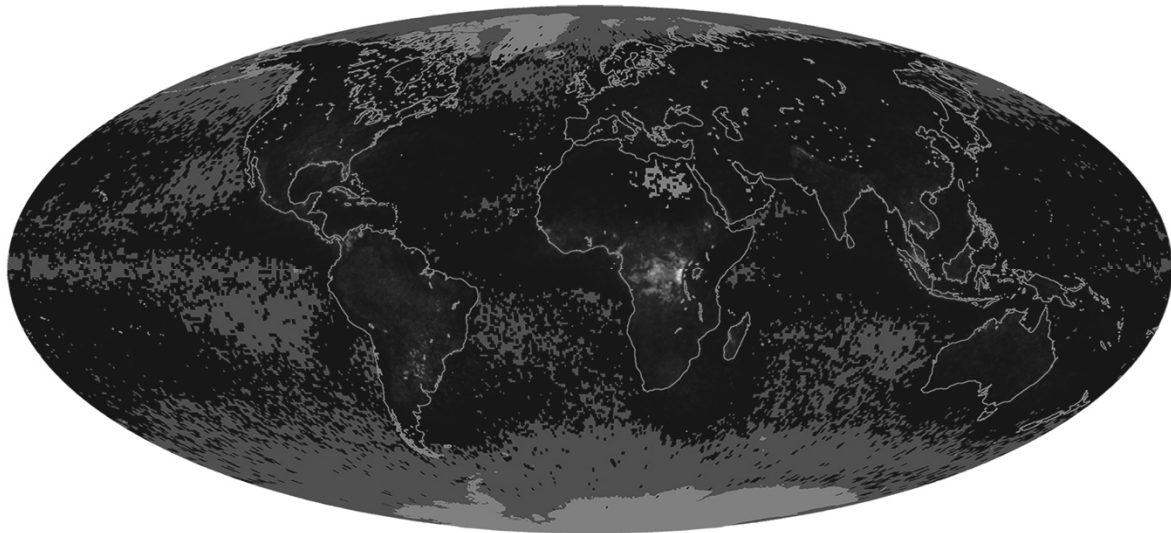
## Isokeraunic Level (Thunderstorm days-TD)

- The number of days in a year when thunder is heard or recorded in a particular location.
  - It does not differentiate between ground strokes and the cloud-to-cloud strokes.
  - Based on past records and experience---
- $N_g = (0.1 \text{ to } 0.2) \text{ TD/strokes/sq.km-year.}$

## Ground flashover density- $N_g$

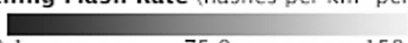
- Ground Flash Density is a measurement of the number of lightning strikes to ground, over a period of one year, averaged by the countries landmass per km<sup>2</sup>. It is known that only about 25 percent of lightning strikes are cloud-to-ground. The rest are either cloud-to-cloud or intra-cloud.
- If  $N_g$  is known, number of flashovers can be computed from the TD level.

Acquired May 4, 1995 - December  
31, 2013

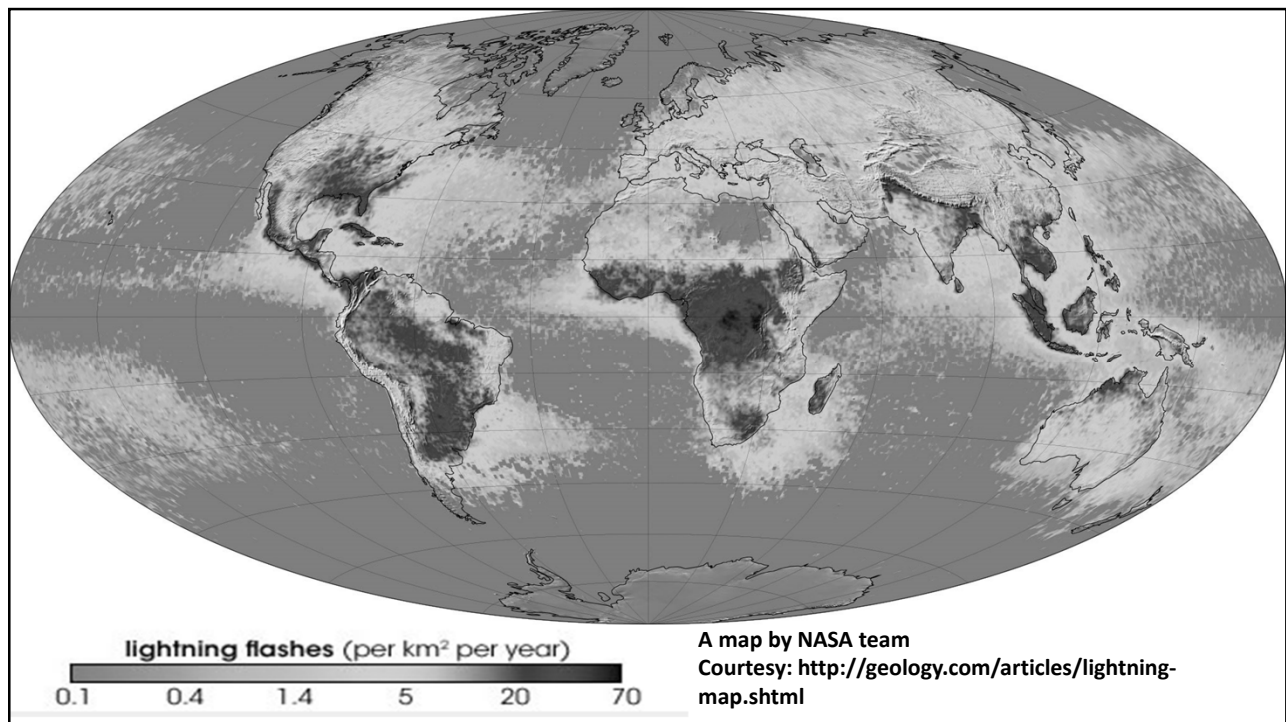


Courtesy:  
<https://earthobservatory.nasa.gov/IOTD//view.php?id=85600>

Lightning Flash Rate (flashes per km<sup>2</sup> per year)



0.1 75.0 150.0



Overvoltage due to Switching Surges, System Faults and other Abnormal Conditions

#### Characteristics of Switching Surges

1. De-energizing of transmission lines, cables, shunt capacitor, banks, etc.
2. Disconnection of unloaded transformers, reactors, etc.
3. Energization or reclosing of lines and reactive loads,
4. Sudden switching off of loads.
5. Short circuits and fault clearances.
6. Resonance phenomenon like ferro-resonance, arcing grounds, etc.

Overvoltage due to Switching Surges, System Faults and other Abnormal Conditions

The other situations of switching that give rise to switching over voltages of shorter duration (0.5 to 5 ms) and lower magnitudes (2.0 to 2.5 p.u.) are:

1. single pole closing SF<sub>6</sub> circuit breaker
2. interruption of fault current when the L-G or L-L fault is cleared
3. resistance switching used in circuit breakers
4. series capacitor compensated lines
5. sparking of the surge diverter located at the receiving end of the line to limit the lightning over voltages

## Overvoltage calculation

- The over voltages due to the above conditions are studied or calculated from
  - (a) mathematical modelling of a system using digital computers
  - (b) scale modelling using transient network analyzers
  - (c) by conducting field tests to determine the expected maximum amplitude of the over voltages and their duration at different points on the line.
- The main factors that are **investigated** in the above studies are
  - (i) the effect of line parameters, series capacitors and shunt reactors on the magnitude and duration of the transients
  - (ii) the damping factors needed to reduce the magnitude of **over voltages**
  - (iii) the effect of single pole closing, restriking and switching with series resistors or circuit breakers on the over voltages, and
  - (iv) the lightning arrester sparkover characteristics.

## Measures to reduce over voltages

- (i) one step or multi-step energization of lines by pre-insertion of resistors,
- (ii) phase controlled closing of circuit breakers with proper sensors,
- (iii) drainage of trapped charges on long lines before the reclosing of the lines,
- (iv) limiting the over voltages by using surge diverters

## Power Frequency over voltages

1. sudden loss of loads,
2. disconnection of inductive loads or connection of capacitive loads,
3. Ferranti effect, unsymmetrical faults, and
4. saturation in transformers, etc.

## Saturation effects

- These magnetizing currents are not sinusoidal in nature but are of a peaky waveform. The third, fifth, and seventh harmonic contents may be 65%, 35%, and 25% of the exciting current of the fundamental frequency corresponding to an overvoltage of 1.2 p.u.
- For **third and its multiple harmonics, zero sequence impedance** values are effective, and **delta connected windings suppress them**. But **the shunt connected capacitors and line capacitances can form resonant circuits and cause high third harmonic over voltages**. When such over voltages are added, the voltage rise in the lines may be significant.
- For **higher harmonics a series resonance between the transformer inductance and the line capacitance can occur which may produce even higher voltages**

## Control of over voltages due to Switching

- The overvoltage due to switching and power frequency may be controlled by
  1. energization of transmission lines in one or more steps by inserting
  2. resistances and withdrawing them afterwards,
  3. phase controlled closing of circuit breakers,
  4. drainage of trapped charges before reclosing,
  5. use of shunt reactors, and
  6. limiting switching surges by suitable surge diverters.