Physics 535A
Physics of Lightning

Lecture 1: Lightning Facts and Stats

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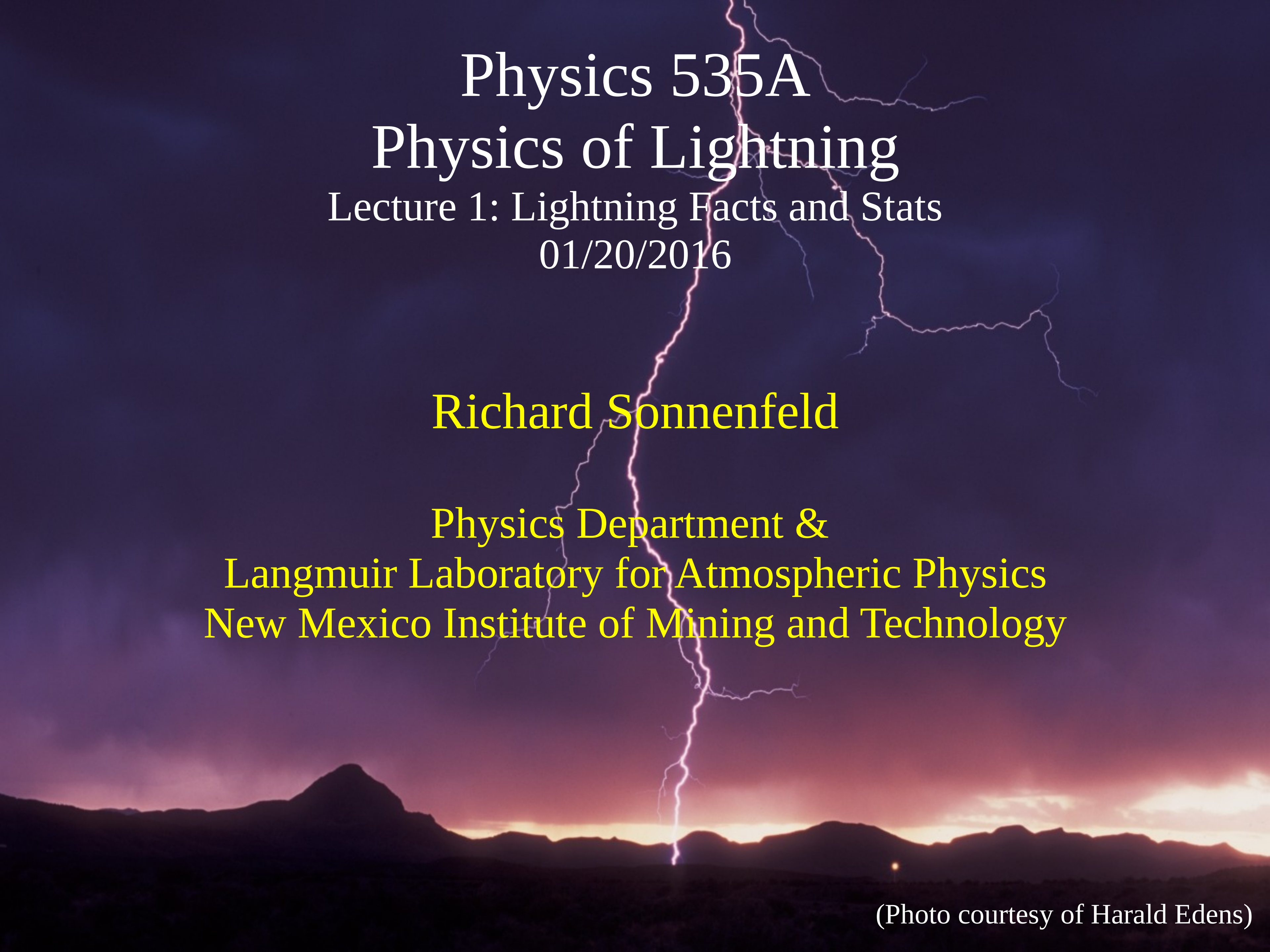
Richard Sonnenfeld

Physics Department &
Langmuir Laboratory for Atmospheric Physics
New Mexico Institute of Mining and Technology



(Photo courtesy of Harald Edens)

Ben Franklin's contributions to lightning science

Lightning is an electrical phenomenon, governed by the same principles as laboratory static electricity.

Most lightning strokes carry negative charge to ground, though some move positive charge to ground.

A noticeable electric field is produced under an active storm.

Theory of "the point" and lightning protection.

(Photo courtesy of Harald Edens)

Outline

- Why study lightning?
- What do we know?
- How a lightning flash develops.
  - Streamers, leaders, attachment and lightning rods.
- Lightning Vocabulary
- Triggered lightning
- Lightning and convection / Energy source for lightning
- Charging Mechanisms
- Charge Structure of clouds
- Lightning Mapping Array
- Operational Meteorology and Climatology
  - Lightning and convection
  - LMA and severe storms
  - Space studies (LIS, OTD, GLM).

Why study lightning?

Lightning kills approximately 100 people/year in US

(1959-1996: NM 85 deaths and 181 injured).

Costs $4-5 Billion/yr in disrupted power lines, destroyed electronics.

Lightning ignites ammunition, fumes, and mine gasses.

Social benefits of lightning research

Understanding of lightning effects on climate change (N2O production)

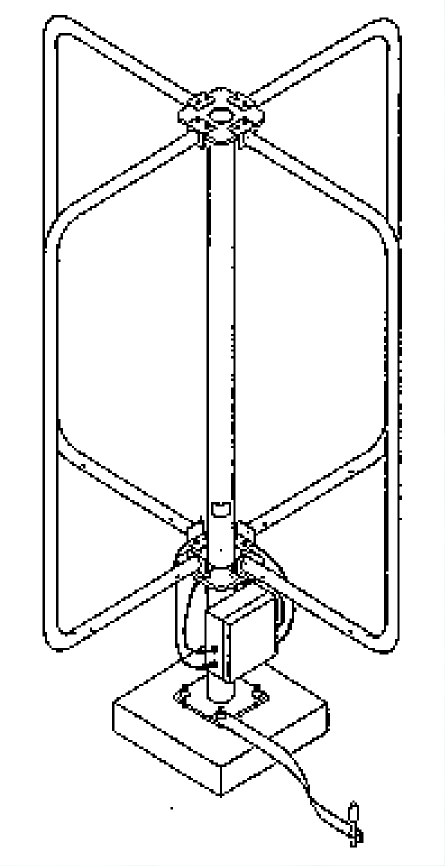
Improved lightning rods

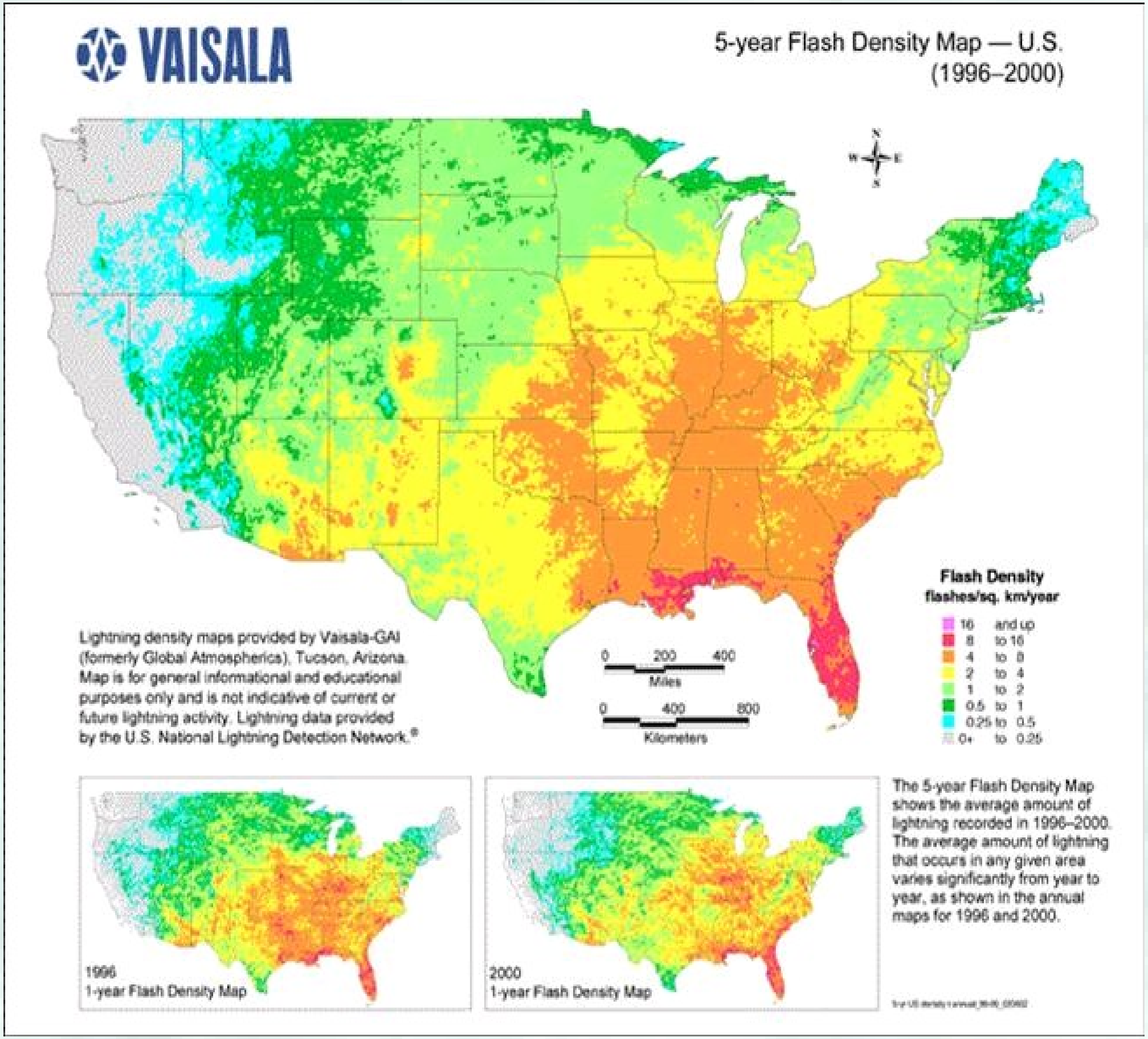
Lightning resistant aircraft

Lightning warning systems / tornado warnings?

Global lightning location networks

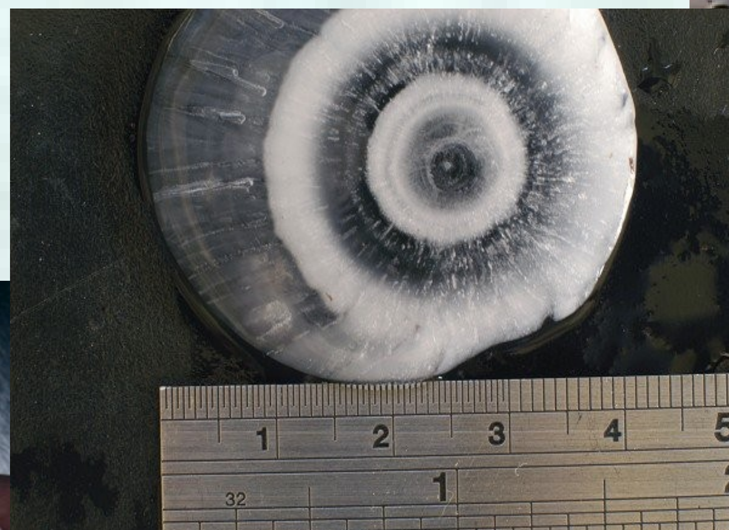
Why study lightning in New Mexico?





Why study lightning in New Mexico?

- Storms are fairly small, isolated, and move slowly
- Usually form over mountains
- Usually not severe (no strong winds, large hail or tornados)



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Lightning Vocabulary

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Lightning Mapping Array

Operational Meteorology and Climatology

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Lightning facts we know now

40 flashes/second on Earth.

Peak current I=100,000 Amps

Voltage V=100 Million Volts

Charge transfer Q=20 Coulombs

Energy E= 1 billion joules

(300 kWatt-hours)

Peak Power?

Channel radius r=1 cm

Stepped Leader velocity 0.001c

Dart Leader velocity 0.1c

Return Stroke velocity 0.5c

(NASA Photo)

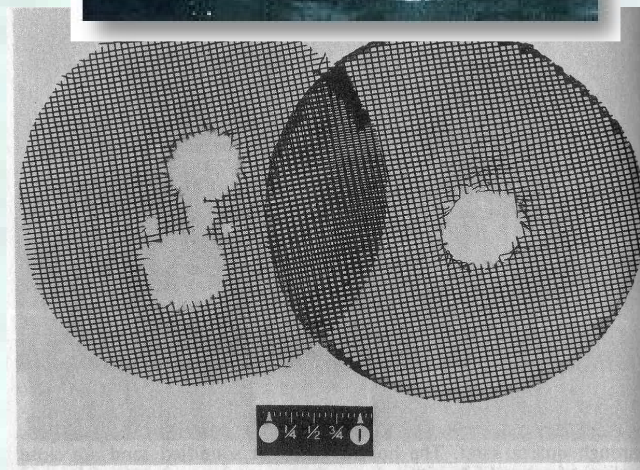

Fig. 10.5. Holes melted in two Fiberglas screens by lightning. At least four strokes passed through the screen on the left. One stroke passed through the screen on the right. From Uman (1971) "All About Lightning"

(From Uman, "All About Lightning "-- 1971)

Basic Calculations

40 flashes/second on Earth.

Peak current I=100,000 Amps

Voltage V=100 Million Volts

$$V = E\Delta z = (2\times10^{4}\,V/m)(5\times10^{3}\,m) = 10^{8}\,V$$

Charge transfer Q=20 Coulombs

Energy E= 1 billion joules

(300 kWatt-hours)

$$U = qV = (20\,C)(10^{8}\,V) = 2\,GJ$$

Peak Power?

$$P = IV = (10^{5}\,A)(10^{8}\,V) = 10\,TW$$

$$P = \frac{\Delta U}{\Delta t} \rightarrow \Delta t = 2\,x\,10^{9}/2\,x\,10^{13} = 100\,\mu s$$

Channel radius r=1 cm

Stepped Leader velocity 0.001c

Dart Leader velocity 0.1c

Return Stroke velocity 0.5c

(From Uman, “All About Lightning “-- 1971)

(Photo courtesy of Harald Edens)

Things we think we know

Where and how frequently does lightning strike in terms of seasons and times of year?

What are the stages of a lightning flash, currents, charges, temperatures?

Where is the charge in a cloud? How much is there? What is its structure?

Partly answered questions

- Charging
  - What REALLY is the charging mechanism?
    - Ice/water tribology?
    - Is ice required for lightning?
- Discharging
  - How does the charge move in a lightning channel?
  - How is lightning able to move so much charge out of a dispersed, non-conductive medium?
  - What triggers lightning strikes?
    - Cosmic Rays?
    - Ice field enhancement?
- What is relation between lightning and precipitation?
  - What triggers rain gush?
- Can a better warning or protection systems be devised?
- Can lightning be used to predict tornadoes?

