Instructor: Doug McCollor
EOSC 114
Wednesday Sept 11, 2024

The Turbulent Atmosphere (Storms)

This Module Covers:

- Thunderstorms
  - lightning, tornadoes, rain, hail, downbursts, etc.
- Atmospheric rivers
- Hurricanes
- Storm Energy
  - saturation, humidity, latent heat
  - solar energy, heat to motion

Videos linked in these Notes provide important (testable) contributions to the Learning Goals.

Homework: Storms Reading (+ Video) and worksheet:
Open Sept 11th / Due Sept 22nd

Road-map to Storm topics

Learning Goals (LG): 1-5

Day	Hazards Risk & Safety	Fundamentals Appearance & Evolution	Energy makes storms
1	Lightning	Thunderstorm basics	sun, radiation, surface heating
2	Rain Downpours, Air Downbursts	Supercells, mesocyclone. Observ.: radar, satellite	moisture, condensation, latent heating
3	Tornadoes	Wall cloud, striations, Doppler radar	
4	Hail, Flooding	Atmos. rivers	heat to motion, forces, winds
5	Flooding, winds, waves, storm surge	Hurricanes	energy in warm ocean, Coriolis

Today's Learning Goals (LG: 1a-e)

By the end of Storms Day 1, you should be able to:

1a) describe different types of lightning, and explain the sequence of events in a lighting strike

1b) explain lightning risk: dangerous times and places; how it affects people; and what you can do to stay safe.

1c) identify and describe typical components of a thunderstorm cloud, and describe the nature and evolution of cells in different types of thunderstorms

1d) explain how solar energy can get into the atmosphere to power storms

1e) list and describe the storm hazards and disaster scales covered in this course.

The Notes that follow indicate which learning goal each slide and video applies to.

(for example: LG: 1a-e)

1. Storm Hazards covered in this course

Learning Goals (LG): 1e

Today

Thunderstorm Hazards

- lightning
- downpours (of rain) / local flooding
- downbursts (of air) / gustfronts
- hail
- tornados

Hurricane Hazards

- contain thunderstorms
- storm surge / coastal flooding
- high waves
- coastal erosion

Lightning - Key Concepts

Learning Goals (LG): 1a

Video Clip

Day1 Video 50 - How Lightning works

(10:58, first 5:30 in class, the rest watch at home) by Pecos Hank.

https://www.youtube.com/watch?v=JXhif3E3l2s

Additional slow-motion videos of the stepped-leader and return strokes to view on your own. Not testable.

Day 1 Video 10: Lightning Science (5:35) (U. Arizona)
https://www.youtube.com/watch?v=66lqGmC-mLY

Day 1 Video 15 - Lightning stepped leader (5:30) (Florida Inst. Tech 2016)
https://www.youtube.com/watch?v=QUIpltFo_fg

Day 1 Video 35 - Beautiful time-lapse movies of lightning storms (2:10) (Pecos Hank), not testable.
https://www.youtube.com/watch?v=8FfTpm2JZLc

Day 1 Video 05 - Lightning: names for different types of lightning. 4:50 (Pecos Hank), not testable.
https://www.youtube.com/watch?v=KO3H285CFRo

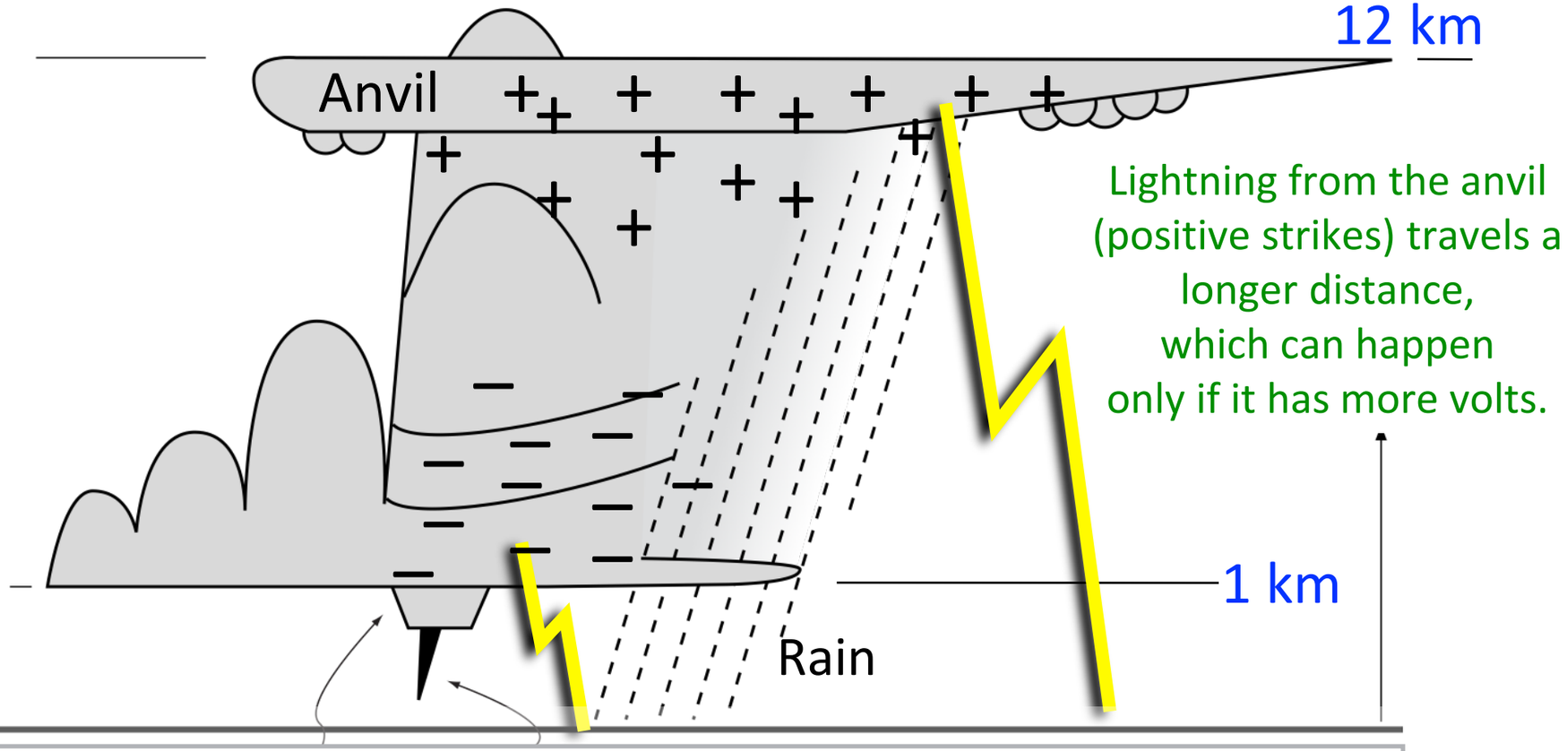
Learning Goals (LG):
1a

The previous video discusses many types of lightning. Two of the most common are shown here.

1 to 10 times more IC than CG

Cloud-to-Ground (CG) Lightning

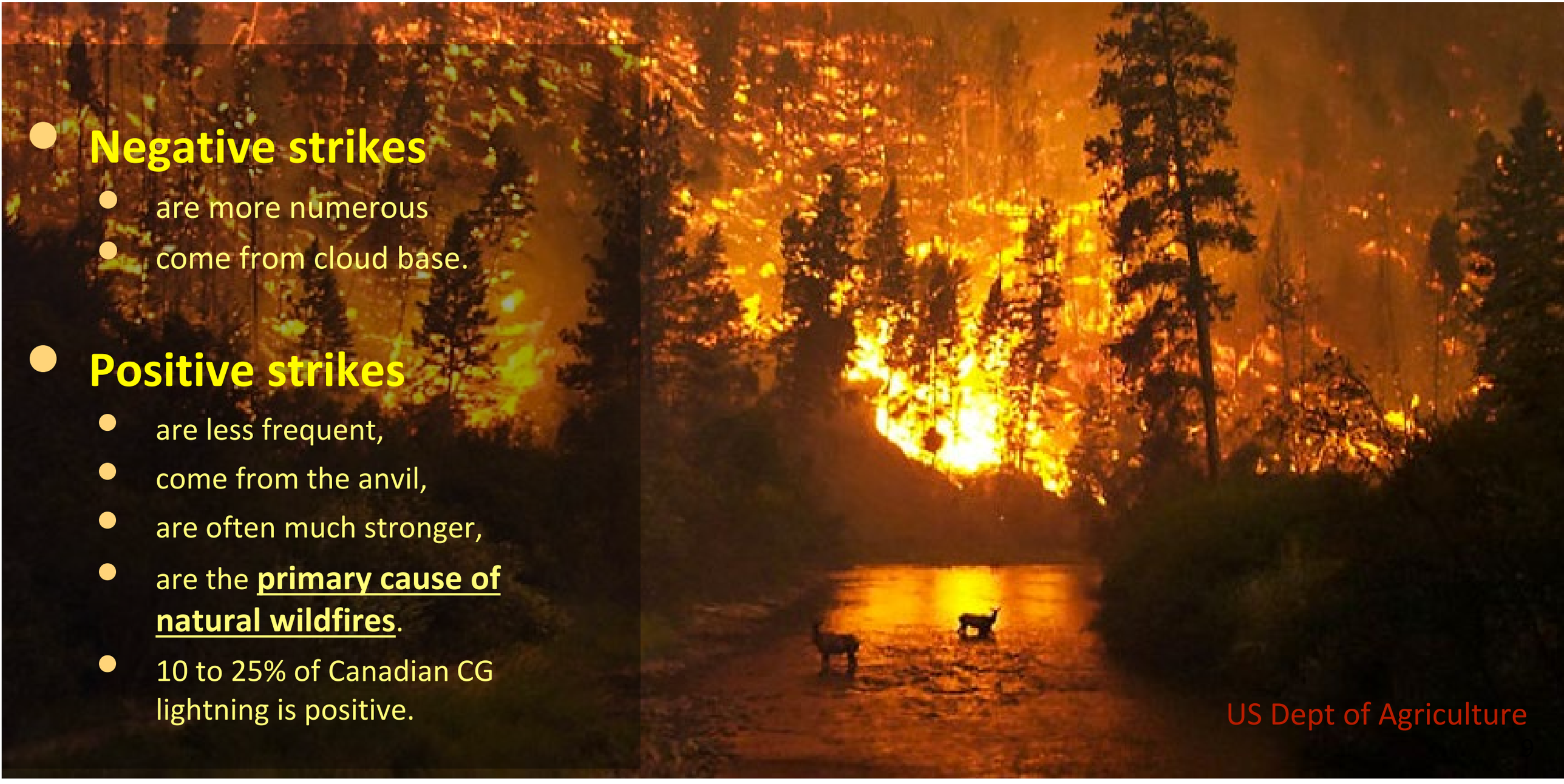
To make a spark in air, you need approximately
3 billion volts / km.



Beyond this course (i.e., not on the exam):
In Canada, over 90% of positive CG has single stroke.
Negative CG can have > 10 strokes, but mode is about 2 strokes/flash.
1% of CGs are ≥ **100** kAmps.

CG Lightning can be Positive (+) or Negative (–)

Learning Goals (LG): 1a, 1b



- **Negative strikes**
  - are more numerous
  - come from cloud base.
- **Positive strikes**
  - are less frequent,
  - come from the anvil,
  - are often much stronger,
  - are the **primary cause of natural wildfires**.
  - 10 to 25% of Canadian CG lightning is positive.

US Dept of Agriculture

Lightning vs. People

Learning Goals (LG): 1b

Percentage of people who survive a lightning strike = 90%

Video 1-20: Explanati… …tning can hit people ou… …v. of Manchester.

…w.youtube.com/watch?v=7QS9Halhqgg

See Homework Assignment

Learn more via the homework assignment:

For more stories of lightning striking people, see:
http://www.outsideonline.com/1925996/body-electric

Medical effects of lightning striking people, see:
http://onlinelibrary.wiley.com/doi/10.1002/wea.2254/pdf

Lichtenberg figure

https://www.nbcnews.com/healthmain/heres-what-lightning-strike-can-do-your-skin-325006

Lightning Hitting a Tree

Learning Goals (LG): 1b

Hazard??

Video Clip

Video Day1-22b

- http://sploid.gizmodo.com/heres-a-lightning-bolt-striking-and-destroying-a-tree-1755618976
- https://i.kinja-img.com/gawker-media/image/upload/s--EhJ6zpRP--/c_fit,fl_progressive,q_80,w_636/niakloquiue1b8a1kgpr.gif

Thanks to: Casey Chan 1/27/16

Not testable: Pecos Hank films lightning setting a tree on fire:
https://www.youtube.com/watch?v=Y-LPERlRHYA

Lightning Hitting a Tree

Learning Goals (LG): 1b

Hazard is shrapnel of tree bark exploding outward.

Video Clip

Video Day1-22b

- http://sploid.gizmodo.com/heres-a-lightning-bolt-striking-and-destroying-a-tree-1755618976
- https://i.kinja-img.com/gawker-media/image/upload/s--EhJ6zpRP--/c_fit,fl_progressive,q_80,w_636/niakloquiue1b8a1kgpr.gif

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What Happens if you are in a Car Struck by Lightning?

Learning Goals (LG):
1a, 1b

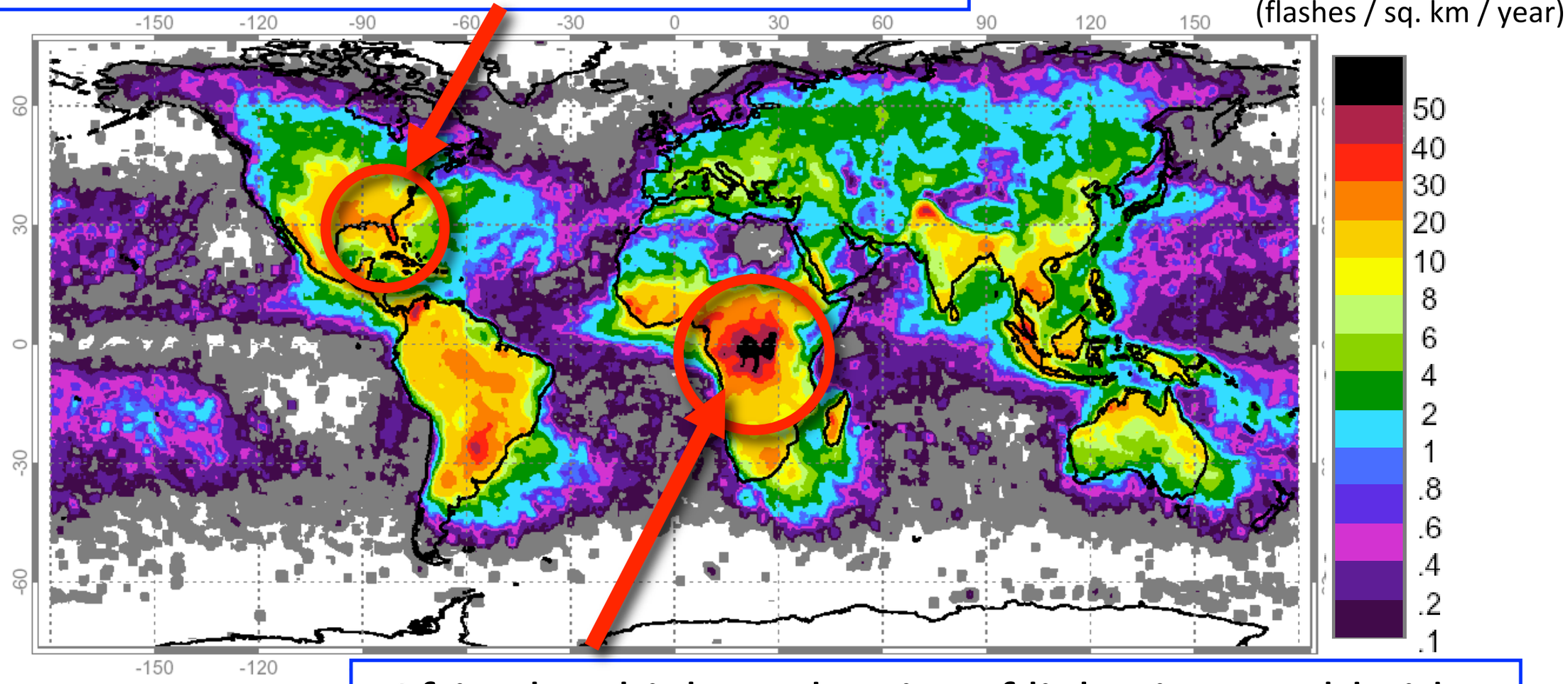
Day1-01— Top Gear. Car struck by Lightning.
(5:00, but watch 1:40 - 4:55)

https://www.youtube.com/watch?v=GZxgYNnkBd0

Similar effects if you are in a metal aircraft.

Lightning Risk Map

Florida is “lightning alley” in N. America.



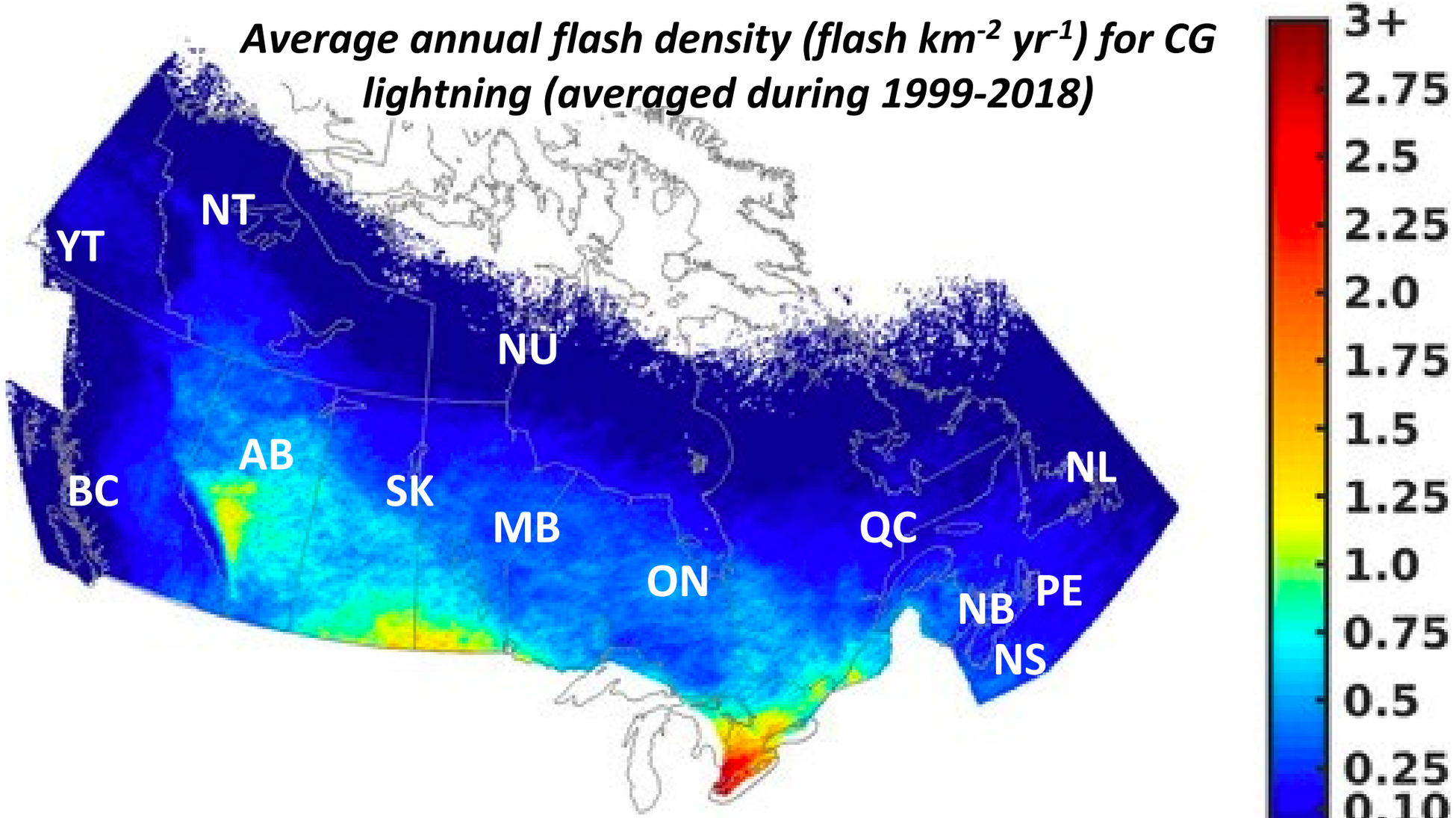
NASA image

Africa has highest density of lightning worldwide.

Lightning in Canada:

~2.4 million cloud-to-ground strikes/year, causing 6 - 12 deaths/year.

Average annual flash density (flash km^{-2} yr^{-1}) for CG lightning (averaged during 1999-2018)



Learning Goals (LG): 1b

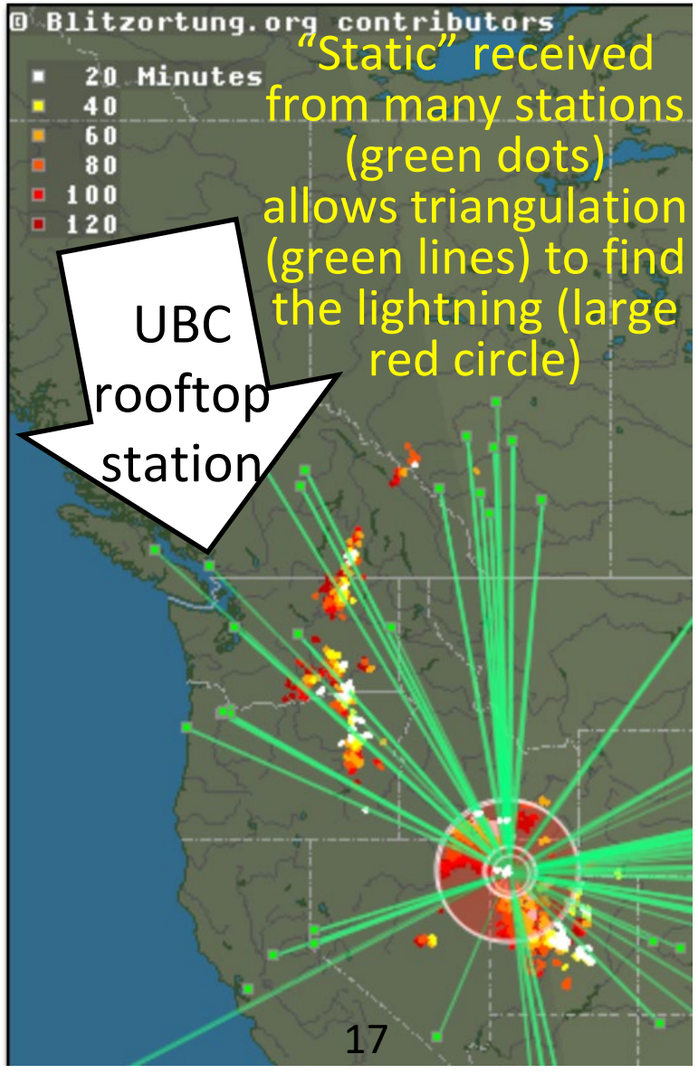
Kochtubajda and Burrows 2020 Atmosphere-Ocean, 58:5, 316-332

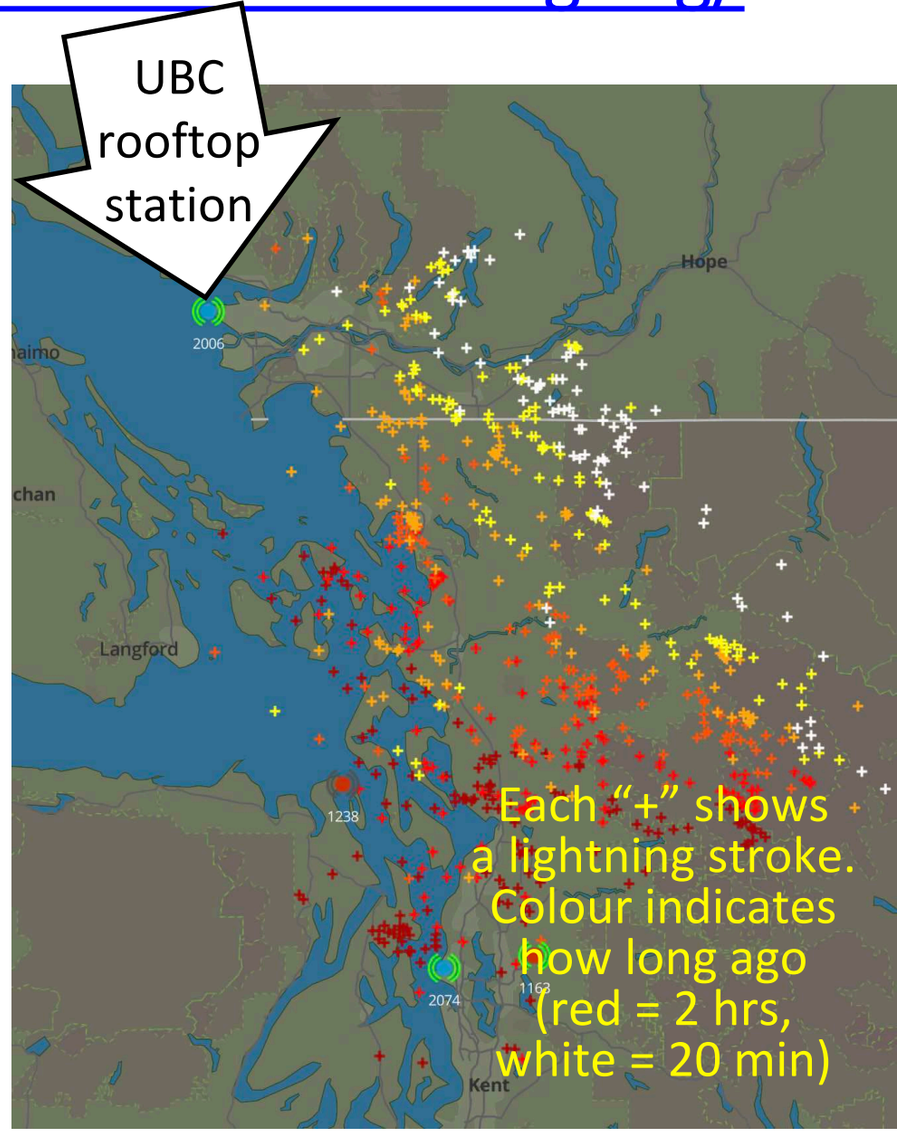
Lightning Detection Networks

Crowd-sourced, world-wide network: http://www.blitzortung.org/

Other networks (not testable)

- wwlln.net
- weather.gc.ca/lightning
- www.vaisala.com (search YouTube for Vaisala lightning)





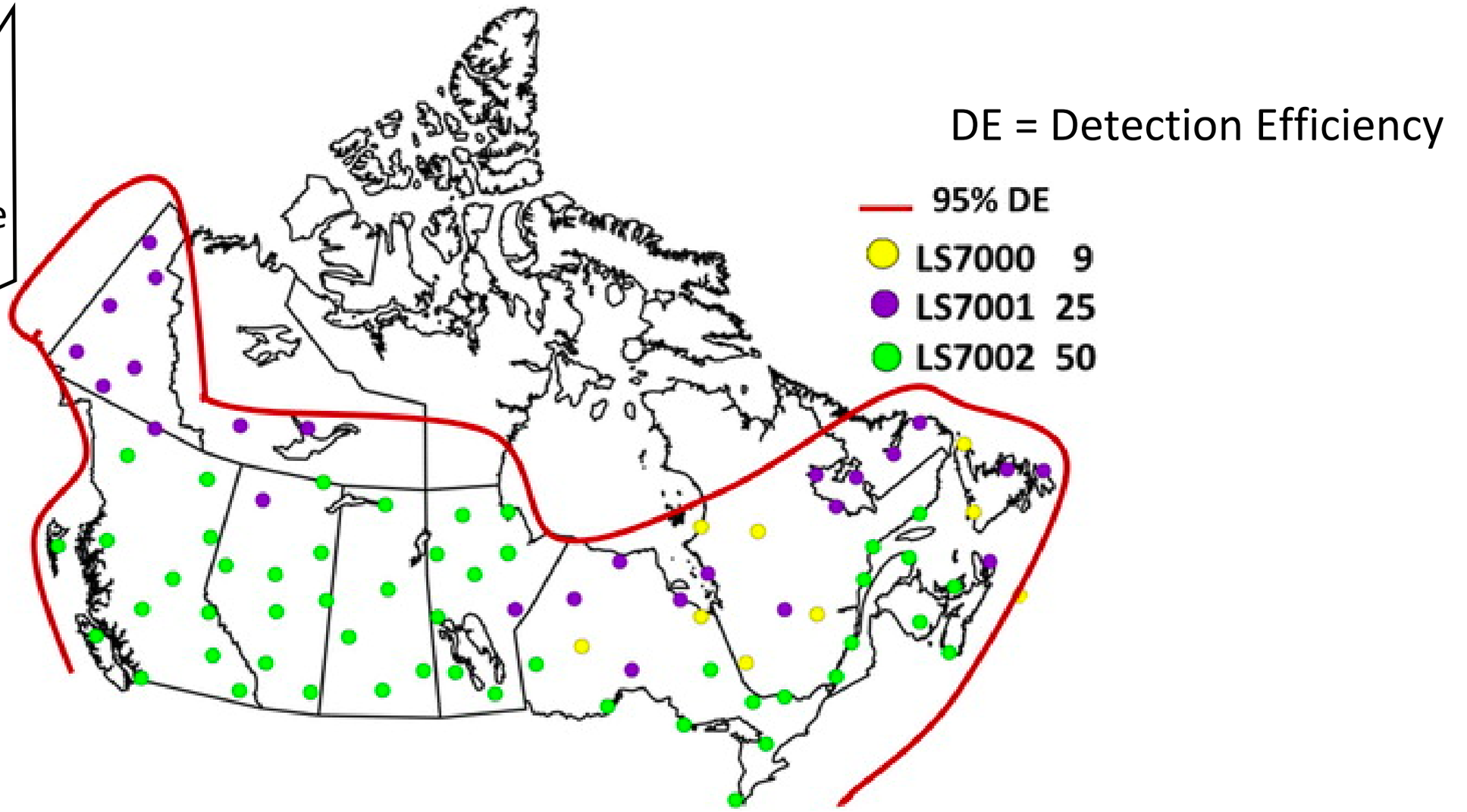
Lightning Detection Networks

Learning Goals (LG): 1b

Canadian Lightning Detection Network

https://www.canada.ca/en/environment-climate-change/services/lightning/canadian-detection-network.html

95% of all strikes within this red line are detected



DE = Detection Efficiency

Lightning Detection from Space

Learning Goals (LG): 1b

Day 1- Video 24. The new GOES 16, 17 & 18 weather satellites have special “optical transient detectors” to observe lightning. (0:44) play 2x speed.

https://www.youtube.com/watch?v=UXlLzFqcGMU

How far away is lightning?

Learning Goals (LG): 1b

- Sound travels more slowly than light.
- Count the number of seconds between when you **see** the lightning and **hear** the thunder.
- Divide that number by 3 to estimate the range in kilometers to the lightning.

Examples: 9 second difference => 3 km .

15 second difference => 5 km.

Lightning Safety

Learning Goals (LG): 1b

Monitor the weather conditions.

30/30 Rule: If **30** seconds or less between when you see the lightning flash and hear thunder, then move indoors and stay there until **30** minutes after last lightning or thunder.

Safe places: (1) fully enclosed metal vehicle with windows up; or (2) substantial permanent building (but don't use hard-wired telephones!)

Lightning Safety
(continued)

Learning Goals (LG): 1b

If stuck outdoors, **avoid** unsafe areas:
- small structures, huts, rain shelters
- nearby metallic objects (pole, fence)
- trees, water, open fields, hill tops,

etc.

If caught in the open, **do** the "Lightning-Safety Crouch" with feet together, hands over ears

If people nearby are struck by lightning, try reviving with CPR

WeatherStock - used under license

Learning Goals (LG): 1b

Just Before a Lightning Strike on a Hill Top

Moments after this photo was taken on the summit of Moro Rock in Sequoia National Park, the person on the left was hit by lightning, and suffered 3rd and 4th degree burns.

The person on the right was thrown 7 m away.

Also on that hill, one man was killed and another injured by lightning that day.

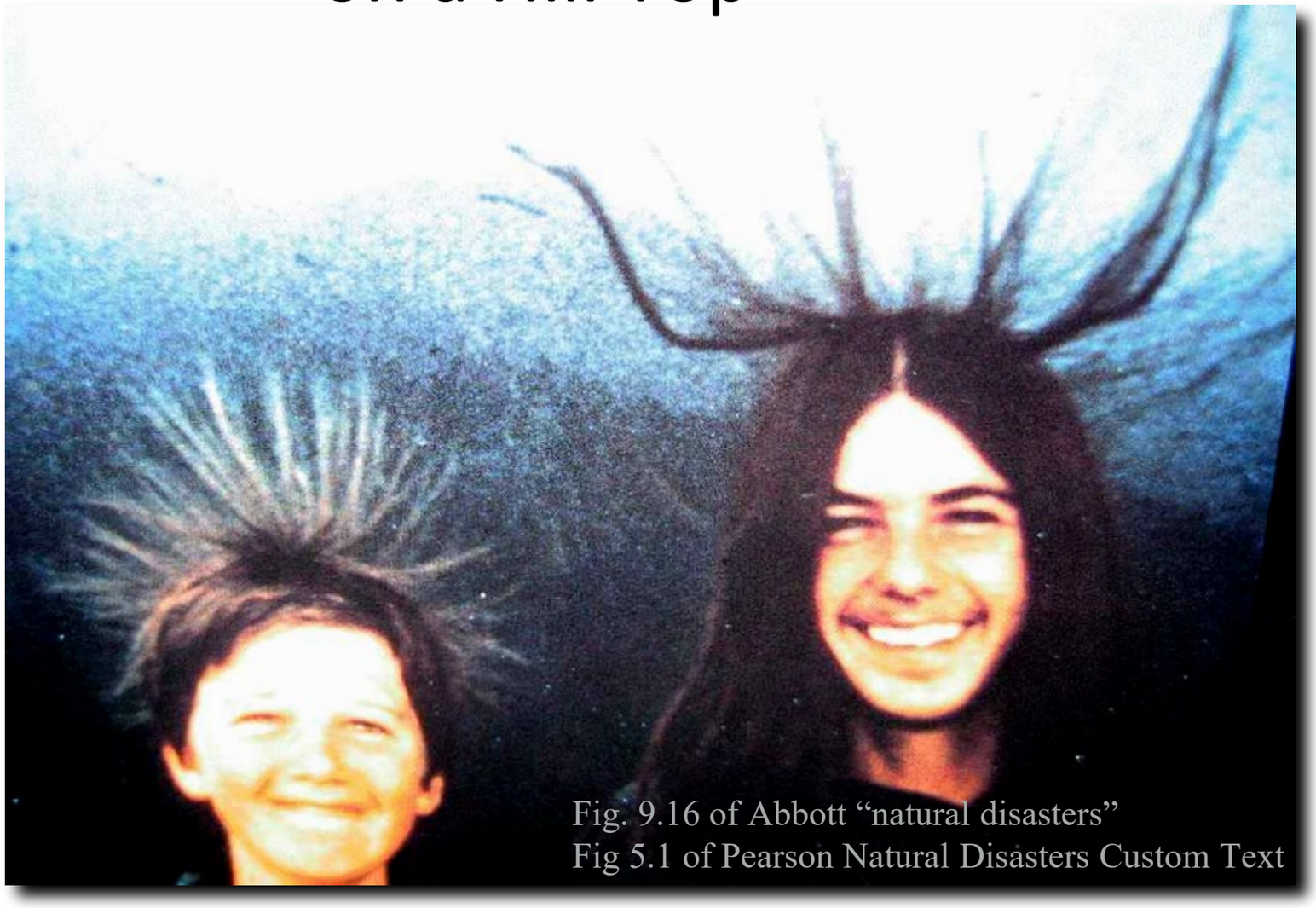
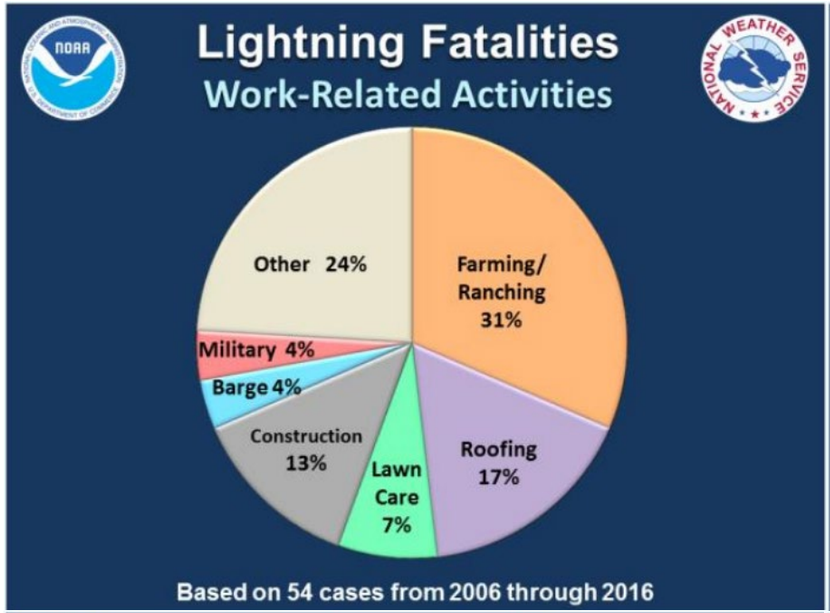
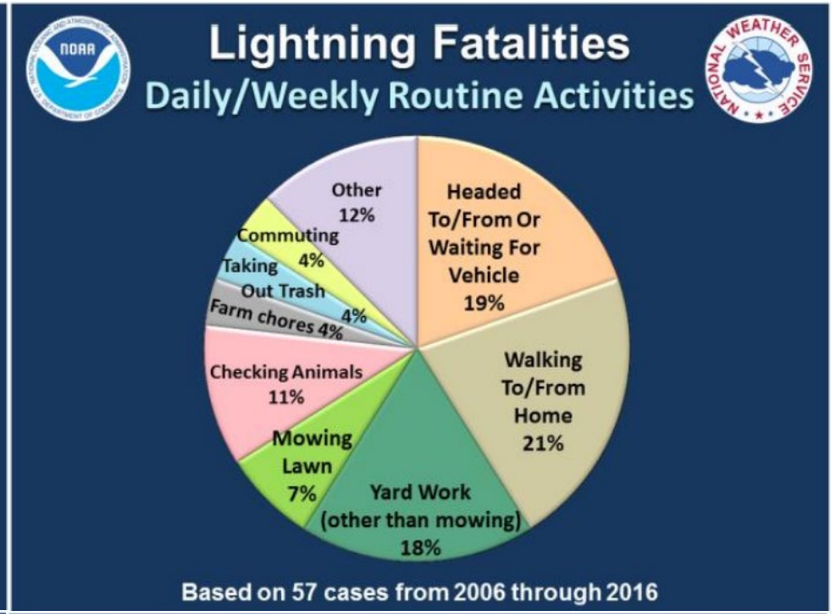
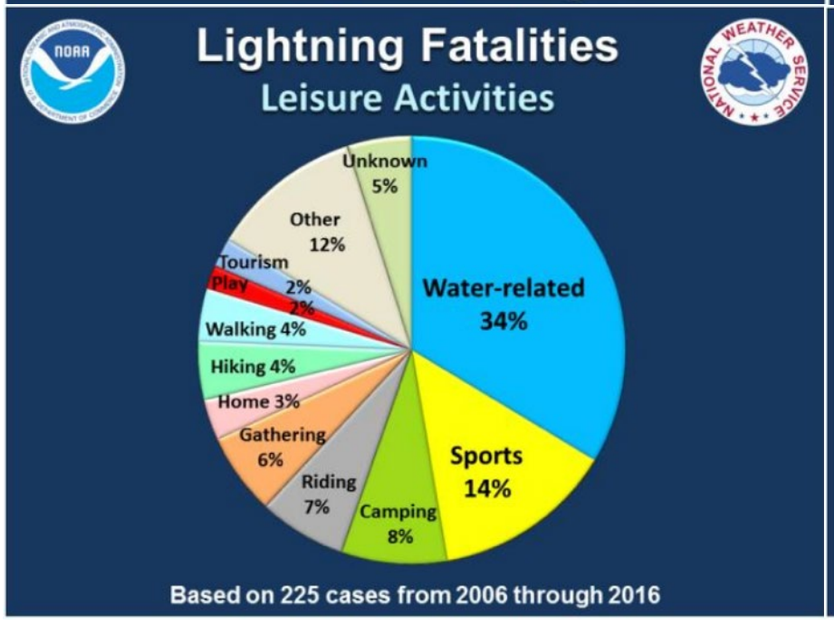


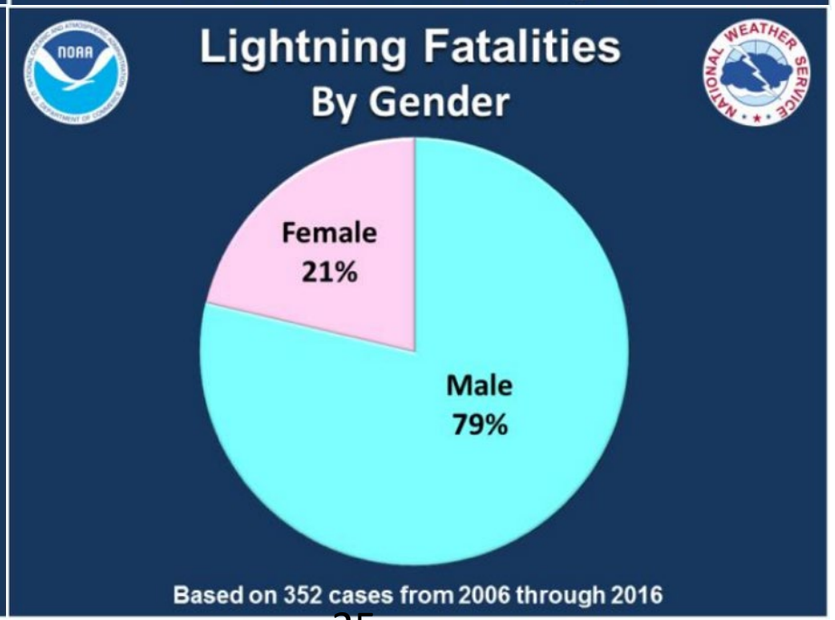
Fig. 9.16 of Abbott "natural disasters"
Fig 5.1 of Pearson Natural Disasters Custom Text

Where are you, in these statistics?









(not testable)

John S. Jensenius, Jr., 2017: A Detailed Analysis of Lightning Deaths in the United States from 2006 through 2016 http://www.lightningsafety.noaa.gov/fatalities/analysis03-17.pdf

Lightning - enjoy the artistry

Learning Goals (LG): 1a, 1b

Not testable, but strikingly beautiful.

Transient, by Dustin Farrell, 2017. Lightning to music. Day 1-03 - (3:18)

https://www.youtube.com/watch?v=nBYZpsbu9ds

Transient 2, by Dustin Farrell, 2019. More Lightning to music. (3:34)

https://www.youtube.com/watch?v=tq1mxZZIuIY

Transient 3, by Dustin Farrell, 2021. More Lightning to music. (7:01)

https://www.youtube.com/watch?v=7Bxvyu2RBOw

Road-map to Storm topics

Learning Goals (LG): 1-5

Day	Hazards Risk & Safety	Fundamentals Appearance & Evolution	Energy makes storms
1	Lightning	Thunderstorm basics	sun, radiation, surface heating
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2. Thunderstorm Basics

Learning Goals (LG):
1c

Thunderstorms are thick clouds with lightning & thunder

cloud top near the top of troposphere (10 - 15 km)

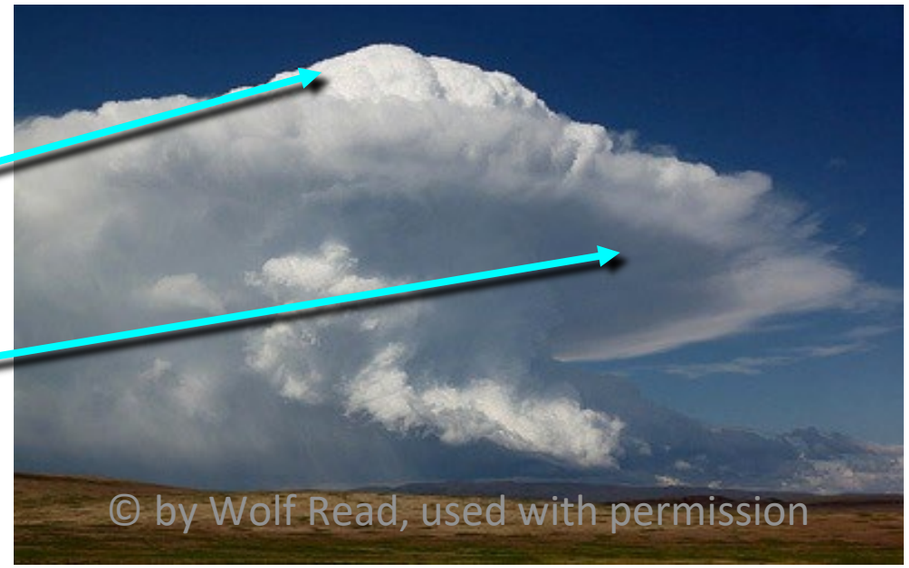
cloud base near ground (altitude ~ 1 km)

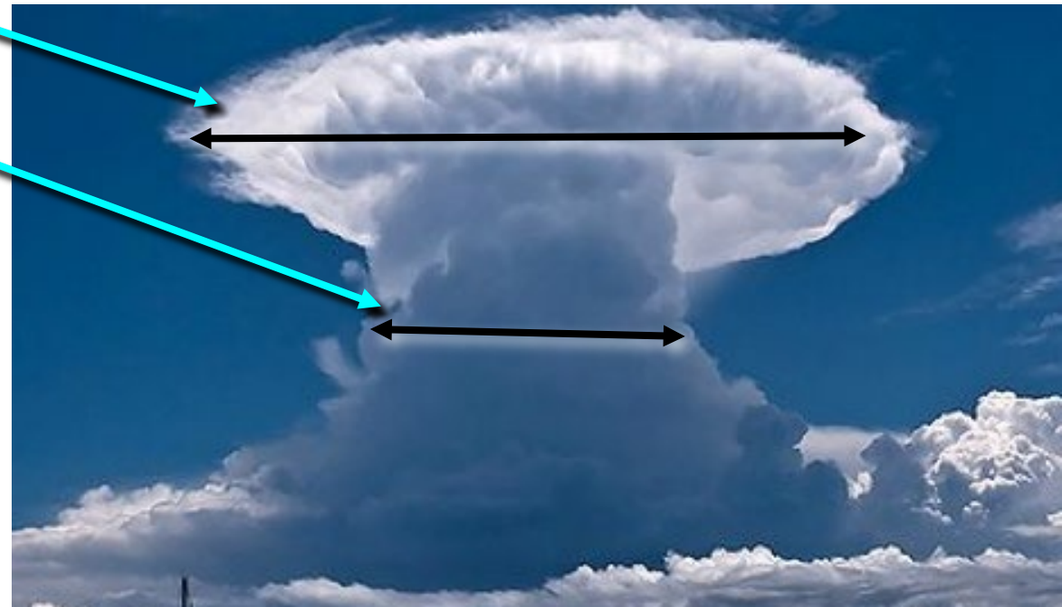
looks a bit like an anvil or mushroom

2. Thunderstorm Basics

Learning Goals (LG):
1c

- strong updrafts & downdrafts (turbulent)
- if very strong updrafts, then dome of clouds overshoot above the anvil
- anvil can be 100s km in diameter.
- main updraft (stem of mushroom) is 15 km diameter.
- storm energy from <u>temperature</u> & <u>humidity.</u>

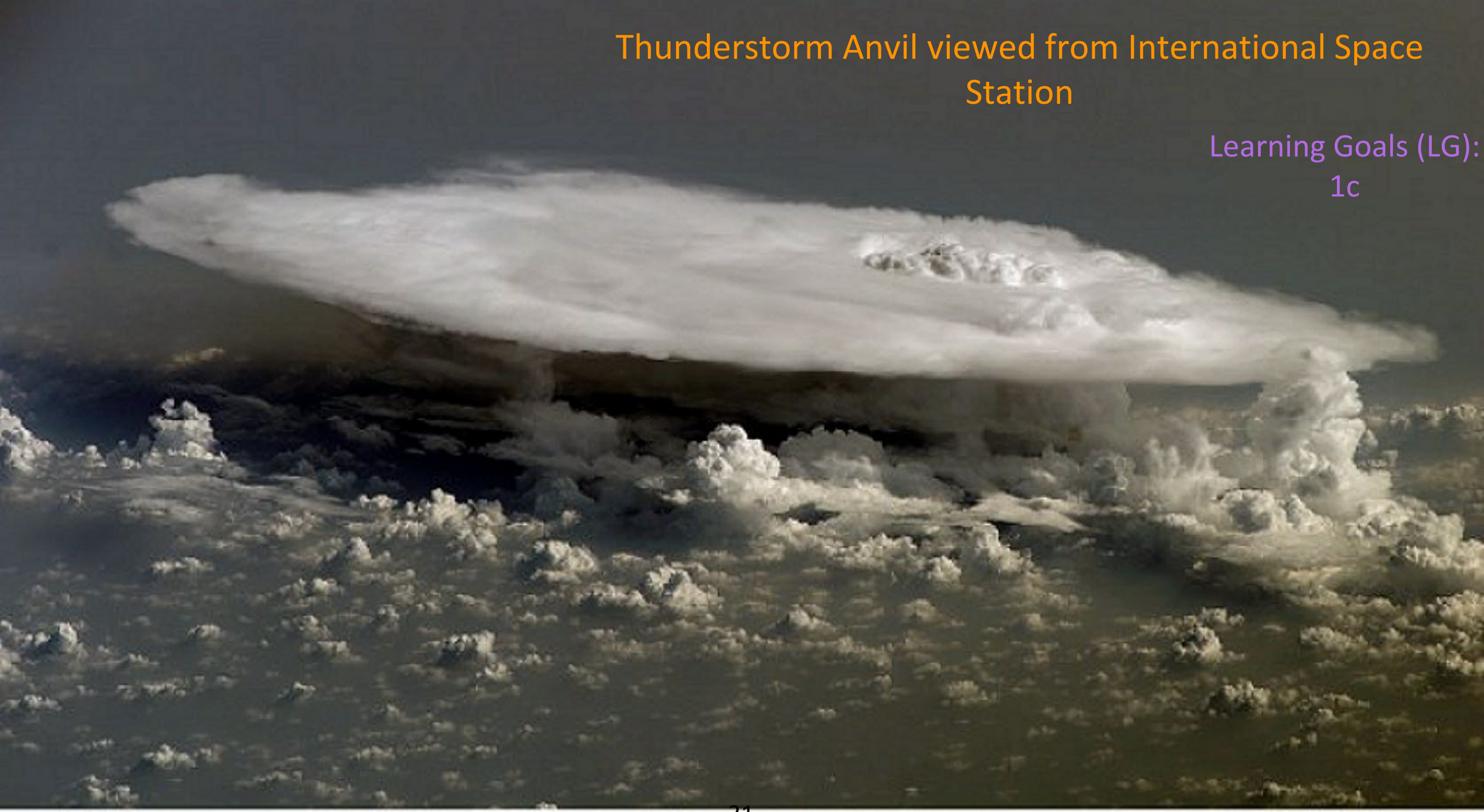




Wikipedia commons

Thunderstorm Anvil viewed from International Space Station

Learning Goals (LG): 1c



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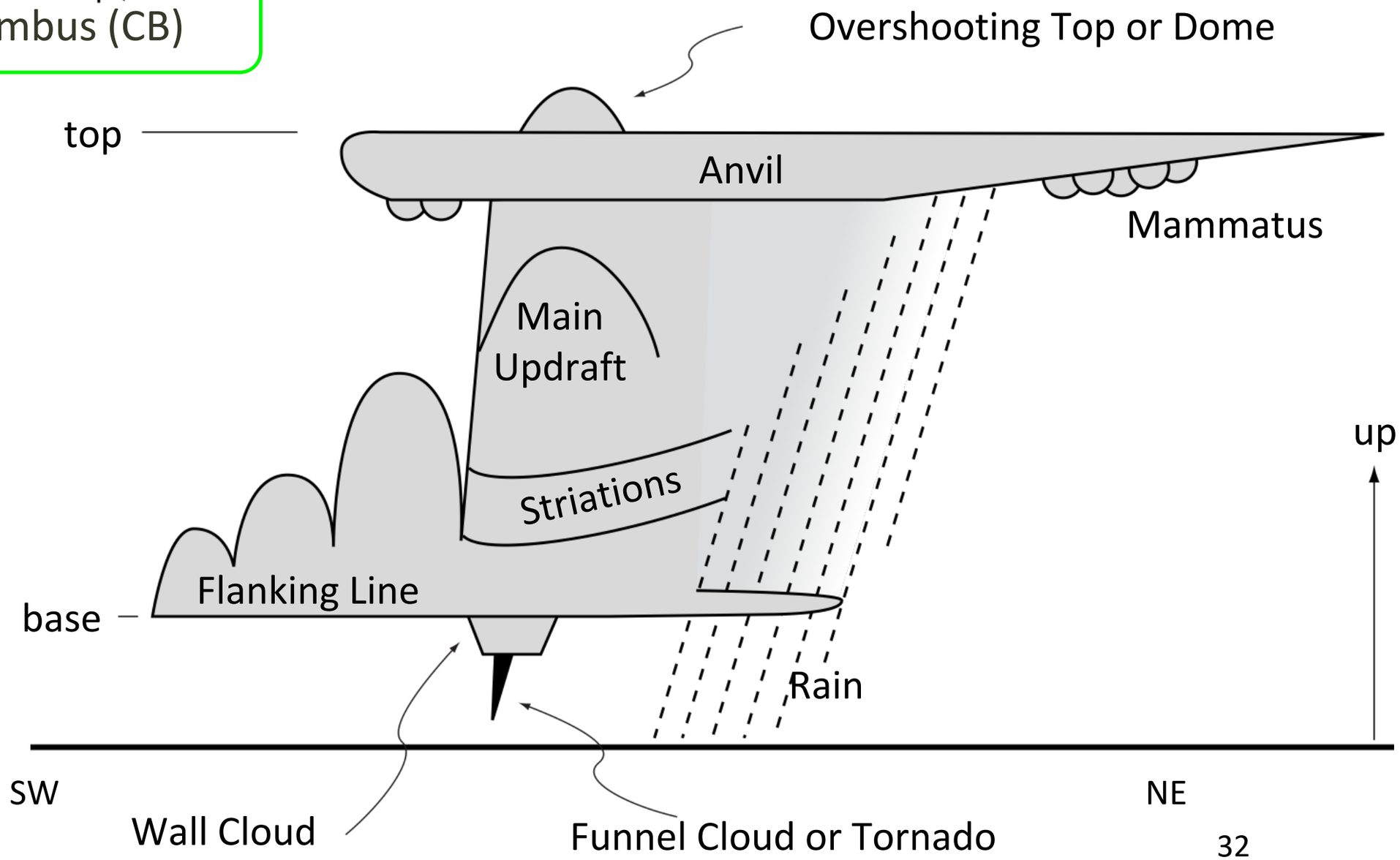
Thunderstorm Appearance

Learning Goals (LG): 1c

Thunderstorm ( ) = Cumulonimbus (CB)



3. Thunderstorm Cells

Learning Goals (LG): 1c,e

Today

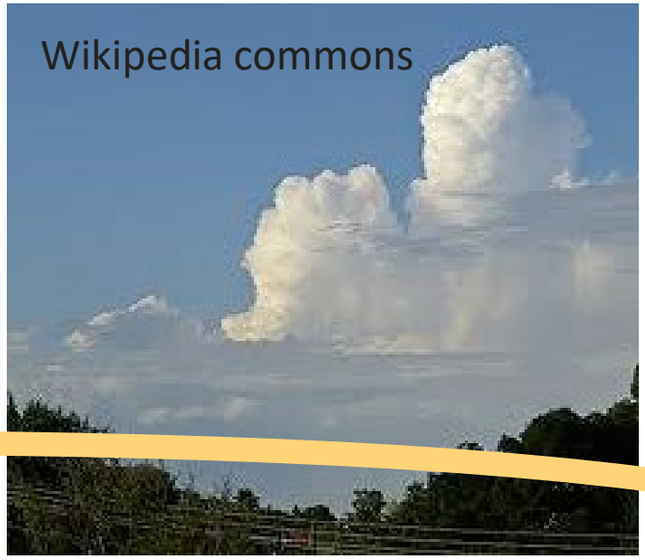
- cumulonimbus (thunderstorms) are made of large cells that evolve during about 15-45 min.
- most thunderstorms contain 2 or more cells, each in different stages of evolution. These are called **multicell thunderstorms** and typically last for longer than any individual cell

Future classes

- **squall line** - a line of thunderstorms
- sometimes a very large, rotating single-cell thunderstorm forms, called a **supercell thunderstorm**. They can cause tornadoes, large hail, frequent lightning, heavy rain, strong winds, and can last for several hours
- Supercell types: low precipitation, classical, high precipitation

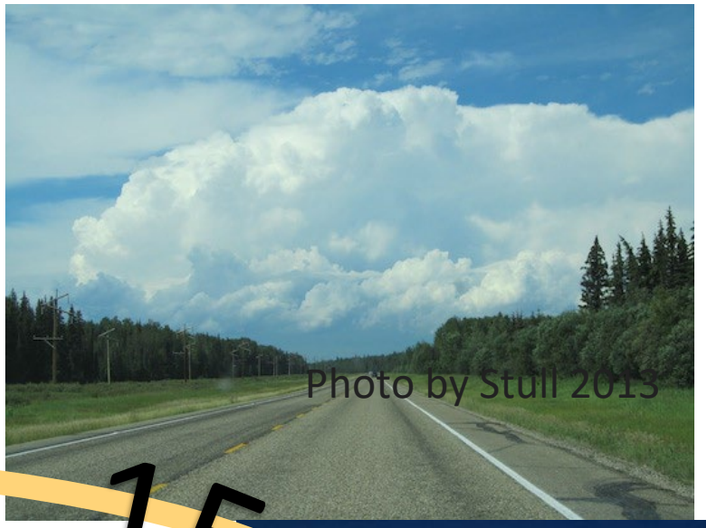
Thunderstorm Cell Life-Cycle

a review in photos



1) Cumulus Stage

updraft, no rain, no anvil



2) Mature Stage

up & down-drafts,
heavy rain, crisp anvil

15-45 mins

3) Dissipating Stage

downdraft, light rain, fuzzy anvil

(The next video shows cell evolution.)

Thunderstorm Cells

Learning Goals (LG):
1c

Day 1 Video 30:

Video of Evolution of a single Thunderstorm cell (1:00):

https://www.youtube.com/watch?v=h6jh4Zp0u08

Another Video to watch on your own (Not testable):

Day 1 Video 25: US National Weather Service

Diagrams: https://www.youtube.com/watch?v=mRVyle6ptlk

Multi-cell Thunderstorms

Learning Goals (LG 1c

Each cell only lasts 15-45 minutes, but the cluster, made up of multiple cells at various stages in their lifecycle, can last for several hours

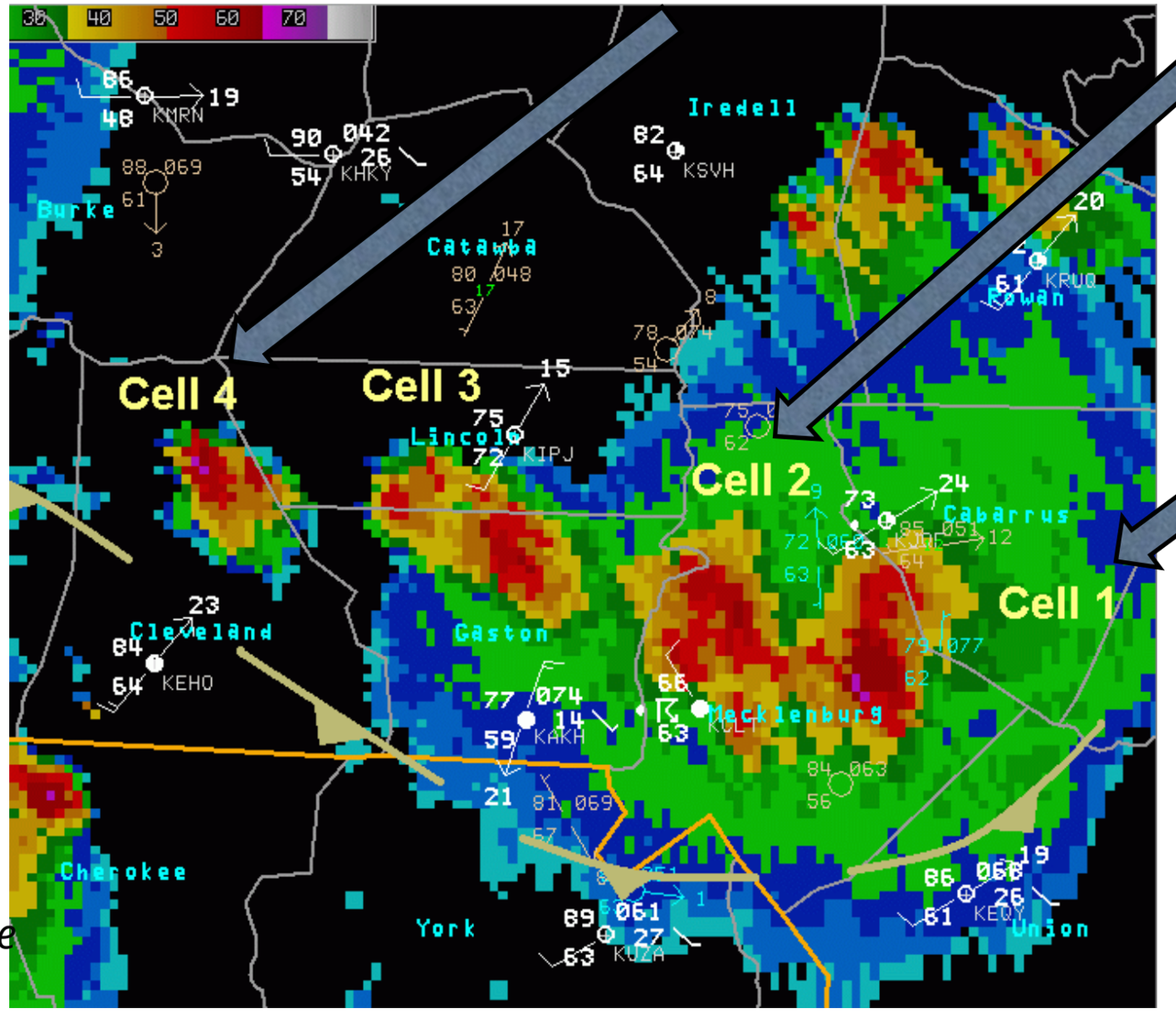
from International Space Station (Over Saudi Arabian desert.)

NASA

Multi-cell Thunderstorms

Learning Goals (LG):
1c

By radar (shows precipitation rate; more on this next class)



From http://www.weather.gov/gsp/26May06Severe

NASA

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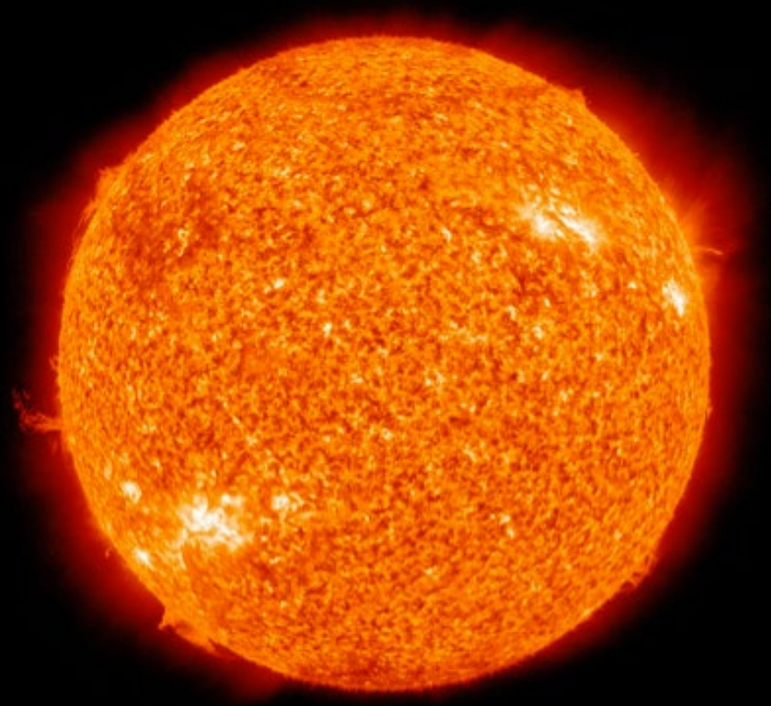
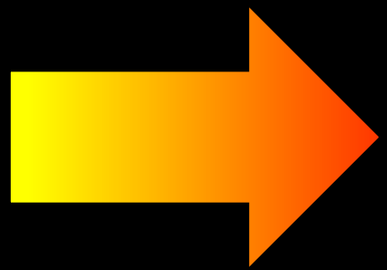
Storm Energy

Learning Goals (LG): 1d

A. Sun – The Source of Atmos. Heat





NASA

NASA

Storm Energy

Learning Goals (LG): 1d

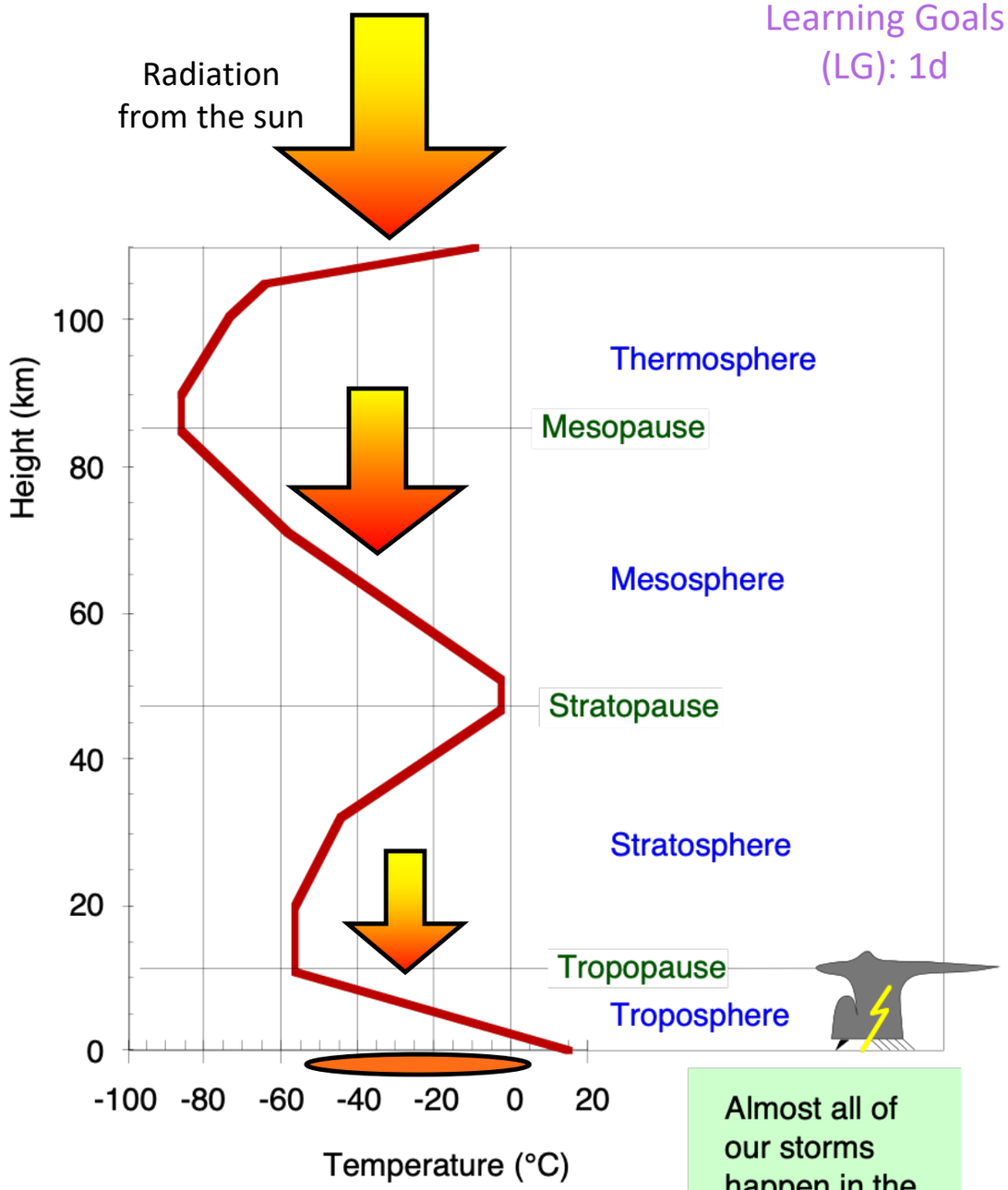
1. Solar energy is absorbed at 3 different heights:

- Top (thermosphere). Absorption of non-visible light

- Middle (stratopause). Absorption of ultraviolet by "good" ozone .

- Bottom (earth surface). Light shines through lower atmos. with little direct heating of air, but heats the ground instead.

Then the warm ground heats air in troposphere (the bottom 11 km), and powers storms.



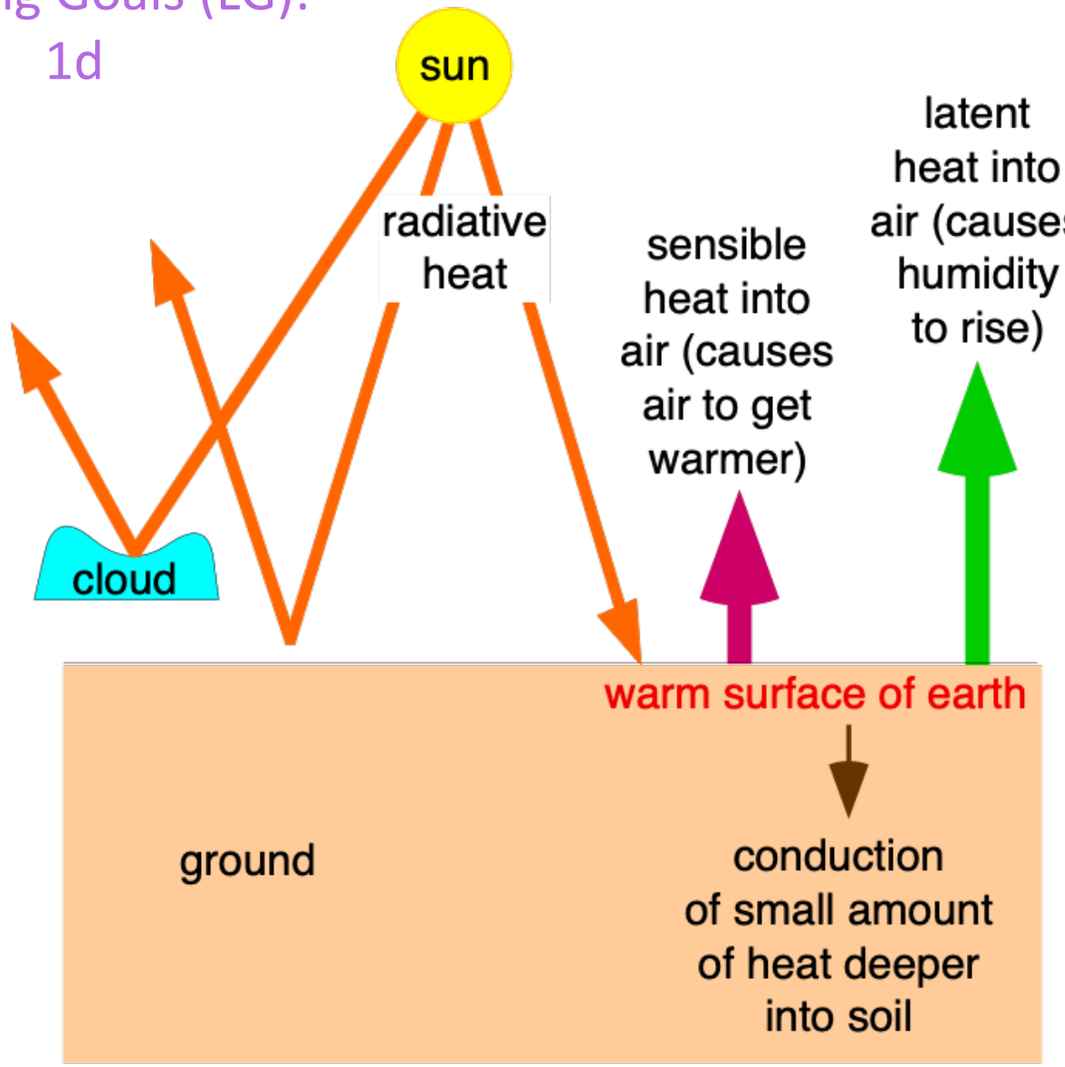
Almost all of our storms happen in the troposphere.

Storm Energy

Learning Goals (LG):
1d

2. Surface Heat Budget

- Some solar energy **reflects** back into space from clouds and the ground.
- Some is **absorbed** by the ground making the ground warmer.
- The warm ground affects the air as follows:
  - **sensible heat** (warms the air) -> air temperature increases.
  - **latent heat** (evaporates water from lakes, vegetation, etc.) -> air humidity increases
- Both **temperature** and **humidity** are important because they are the **fuel for storms**!

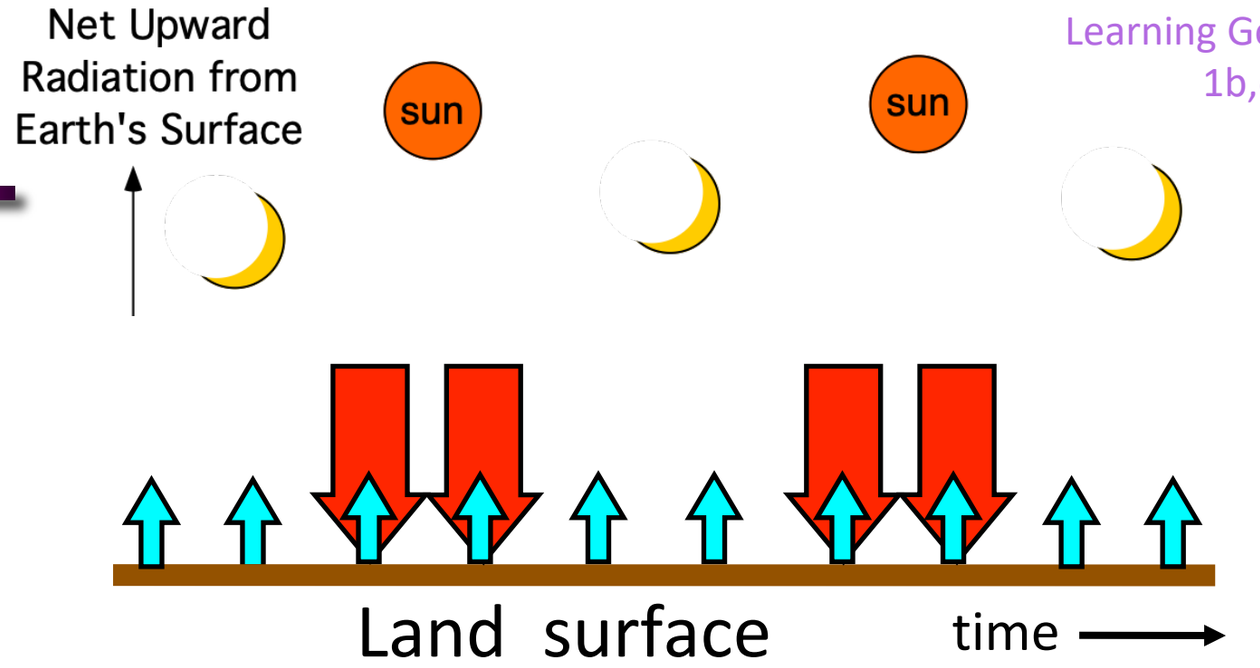


heat input to surface = sum of all heat outputs

Storm Energy

Learning Goals (LG): 1b,d

3. Daily Cycle



- **solar heating** during day => **input** (like charging a battery)

- **infrared radiation (IR) cooling** day & night -> **loss** (like discharge)

- ==> greatest **accumulation of heat**, near sunset every day (at end of each charging cycle).

Late afternoon and early evening => most likely **time of day** for Tstorm formation.

Storm Energy

Learning Goals (LG): 1b,d

3. Daily Cycle

- **solar heating** during day => **input** (like charging a battery)

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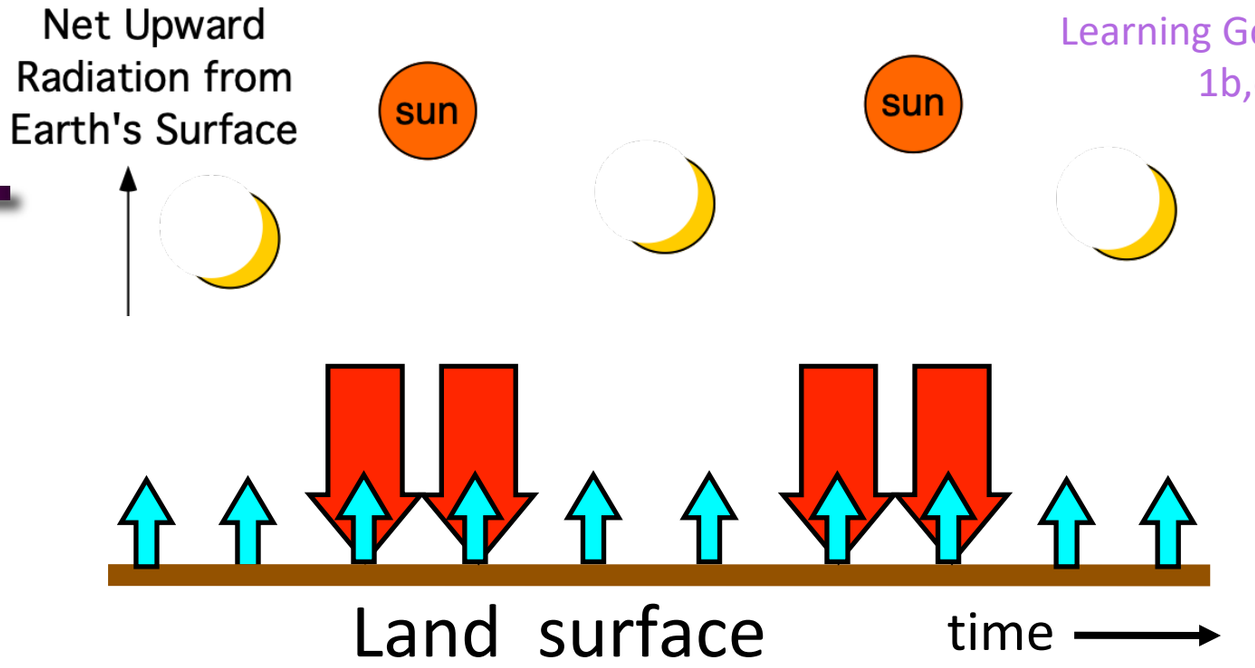
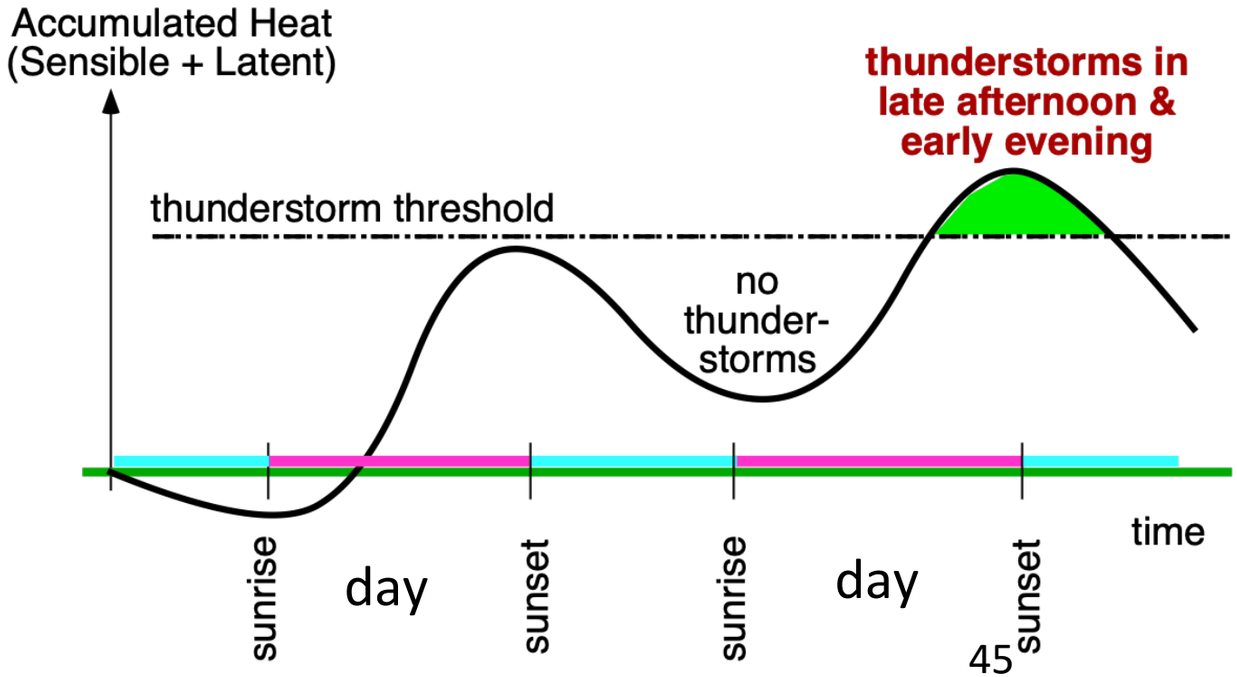
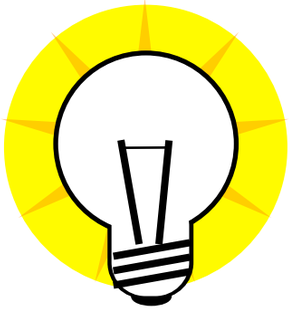




Insights

Learning Goals (LG): 1-5



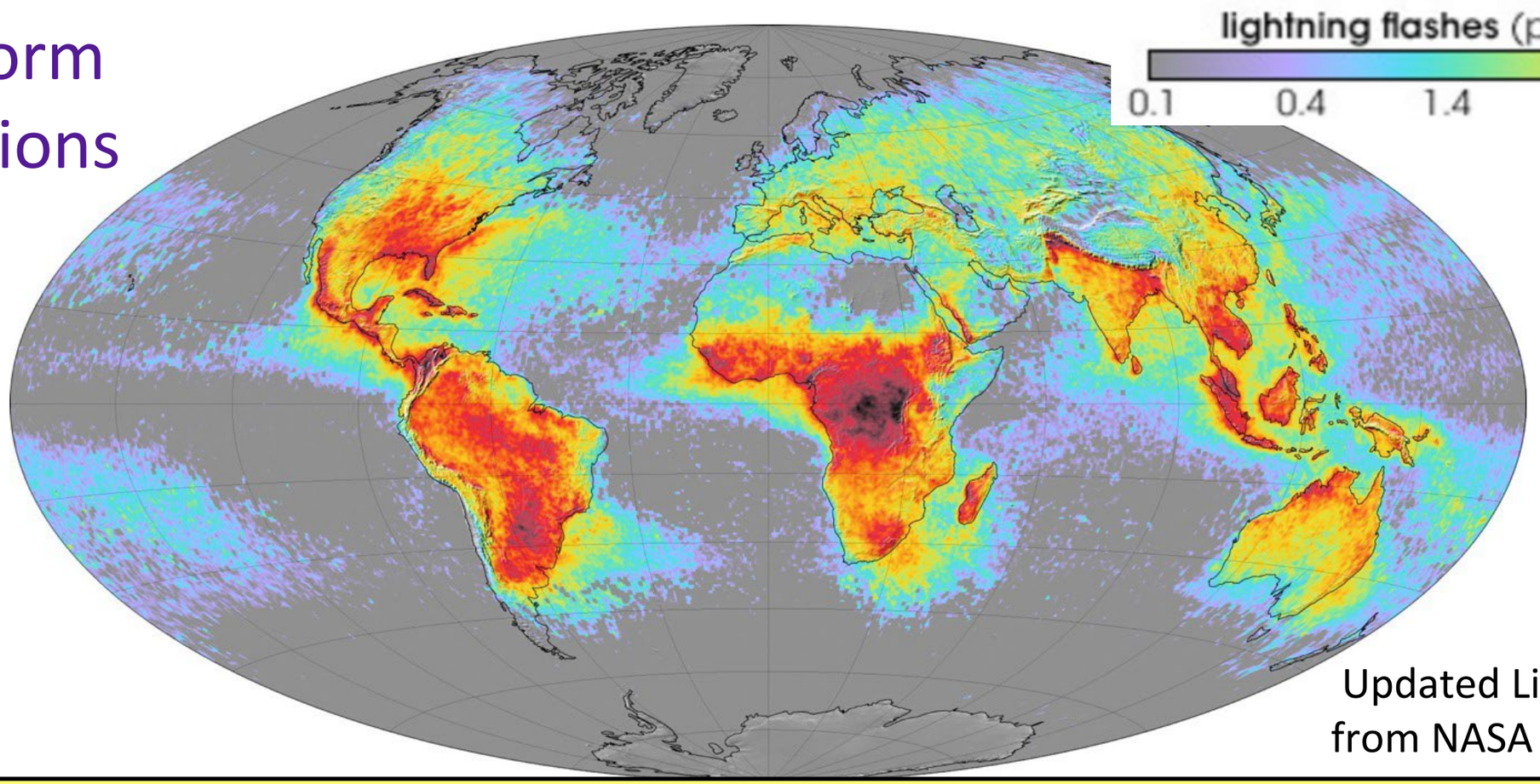
- ☑ Some phenomena must satisfy budgets (such as a heat budget).

Budgets can help you anticipate the constraints on a system.

Storm Energy

Learning Goals (LG): 1b,d

3. Storm Locations



Updated Lightning Risk Map, from NASA Earth Observatory

Favorable Thunderstorm **locations** at greatest supply of **heat** and **moisture**:

- Closer to **equator** -> warm ocean currents -> **warm, humid air.**
- In USA -> **Florida** , Gulf states.
- In Canada -> prairies and central, because of **Advection** (warm humid air carried by the wind) and high temperatures

Storms: The Turbulent Atmosphere

Instructor: Doug McCollor

Summary of Day 1:

1. Storm Hazard List.
   - Focus on Lightning
2. Thunderstorm Basics
3. Thunderstorm Cells

+ Storm Energy A:
  Sun – the source of storm energy

Next Class:

- Supercell thunderstorms & mesocyclones
- Hail and Rain
- Storm Energy B:
  Humidity – the fuel for storms