EOSC 114 - Storms

Learning Goals
(LG): 1 - 4

A video "Teaser", while students enter the classroom.

Day 1 - Video 00 — "Pursuit" a Storm Time Lapse video by Mike Oblinski. (7:37)

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

The Turbulent Atmosphere (Storms)

Prof. Roland Stull

This Module Covers:

- Thunderstorms
  - lightning, tornadoes, rain, hail, downbursts, etc.
- 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.

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) identify atmospheric layers and explain how they relate to storms

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

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

Thunderstorm Hazards

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

Hurricane Hazards

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

Lightning - Key Concepts

Video Clip

Day1 Video 50 - How Lightning works
(10:58) 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

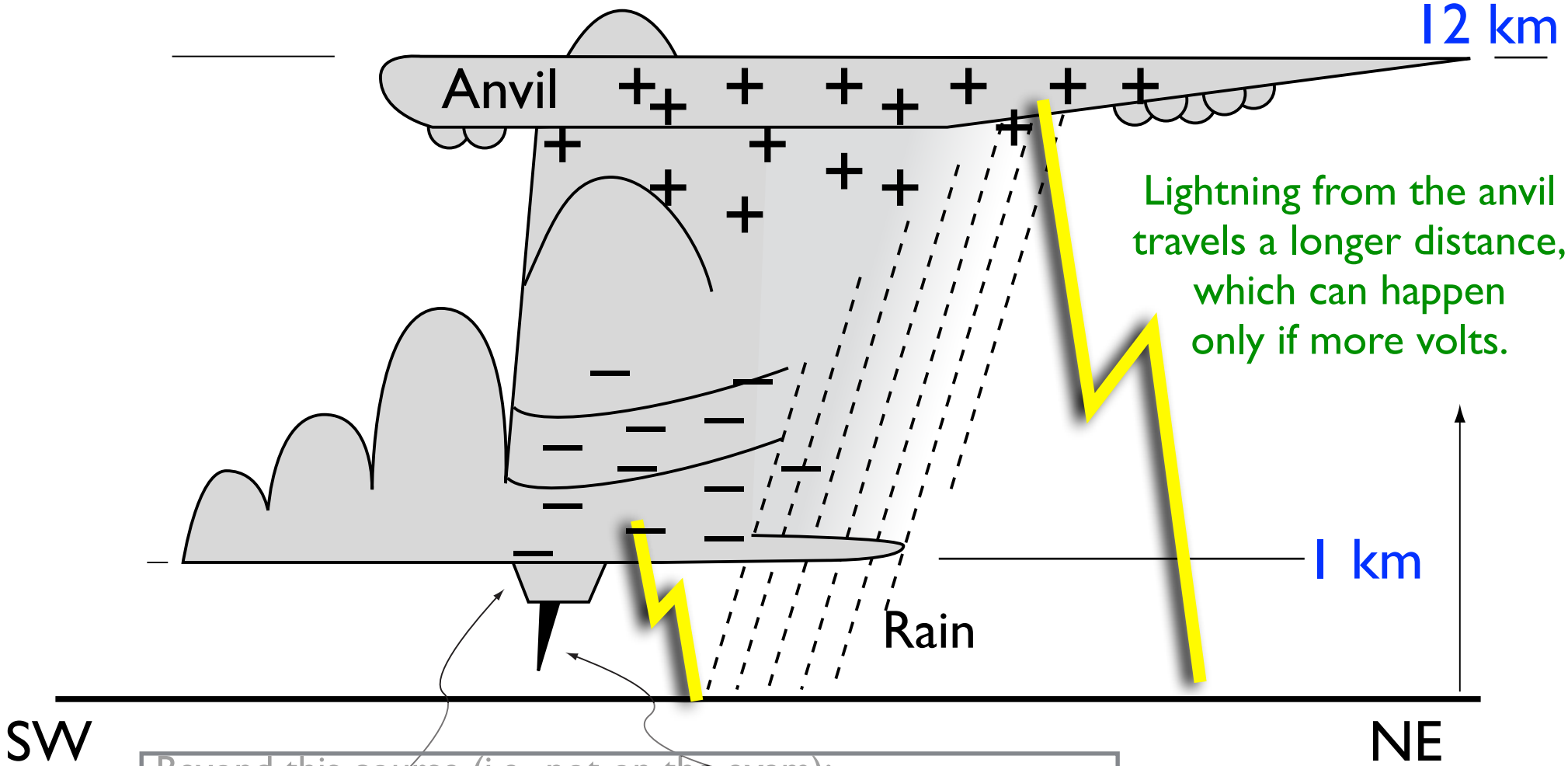
Day 1 Video 05 - Lightning: names for different types of lightning. 4:50 (Pecos Hank), not testable. https://www.youtube.com/watch?v=KO3H285CFRo

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

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 play the portion 1:25 - 4:55)

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

Similar effects if you are in a metal aircraft.

Lightning vs. People

Learning Goals (LG): 1b

- Portion of people who survive a strike = 90%

Video 1-20: Explanation of 3 ways lightning can hit people outdoors, from Univ. of Manchester. (start at 0:45, end at 3:45)

https://www.youtube.com/watch?v=7QS9Halhqgg

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

at a high school in Texas

Hazard is shrapnel of tree bark exploding outward.

Video Clip

Video Day1-22b

Thanks to: Casey Chan 1/27/16

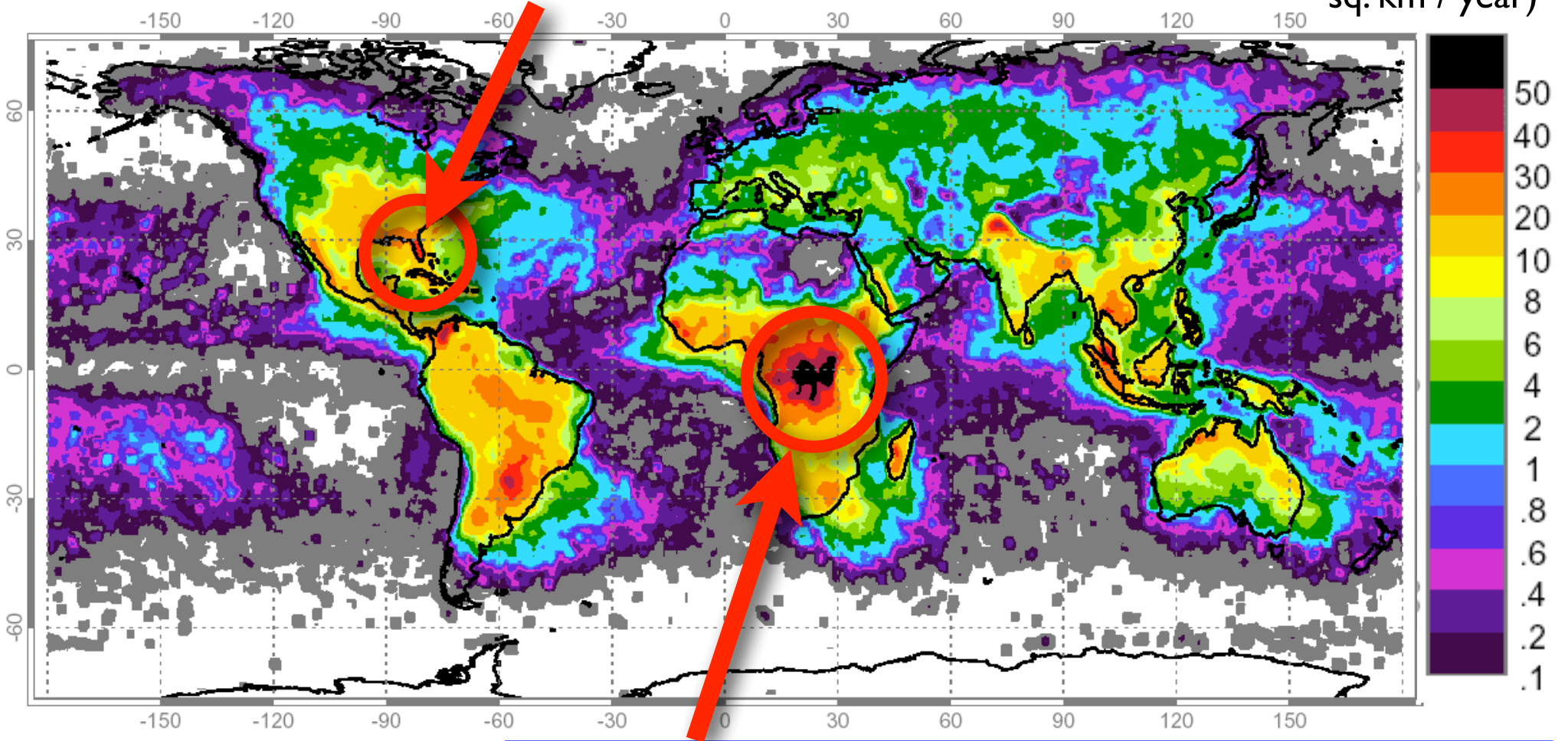
- http://sploid.gizmodo.com/heres-a-lightning-bolt-striking-and-destroying-a-tree-1755618976
- https://i.kinja-img.com/gawker-media/image/upload/s--EhJ6zpRP--/c_fit,fl_progressive,q_80,w_636/niakloquiue1b8a1kgpr.gif

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

Lightning Risk Map

Learning Goals (LG): 1b

Florida is "lightning alley" in N. America.

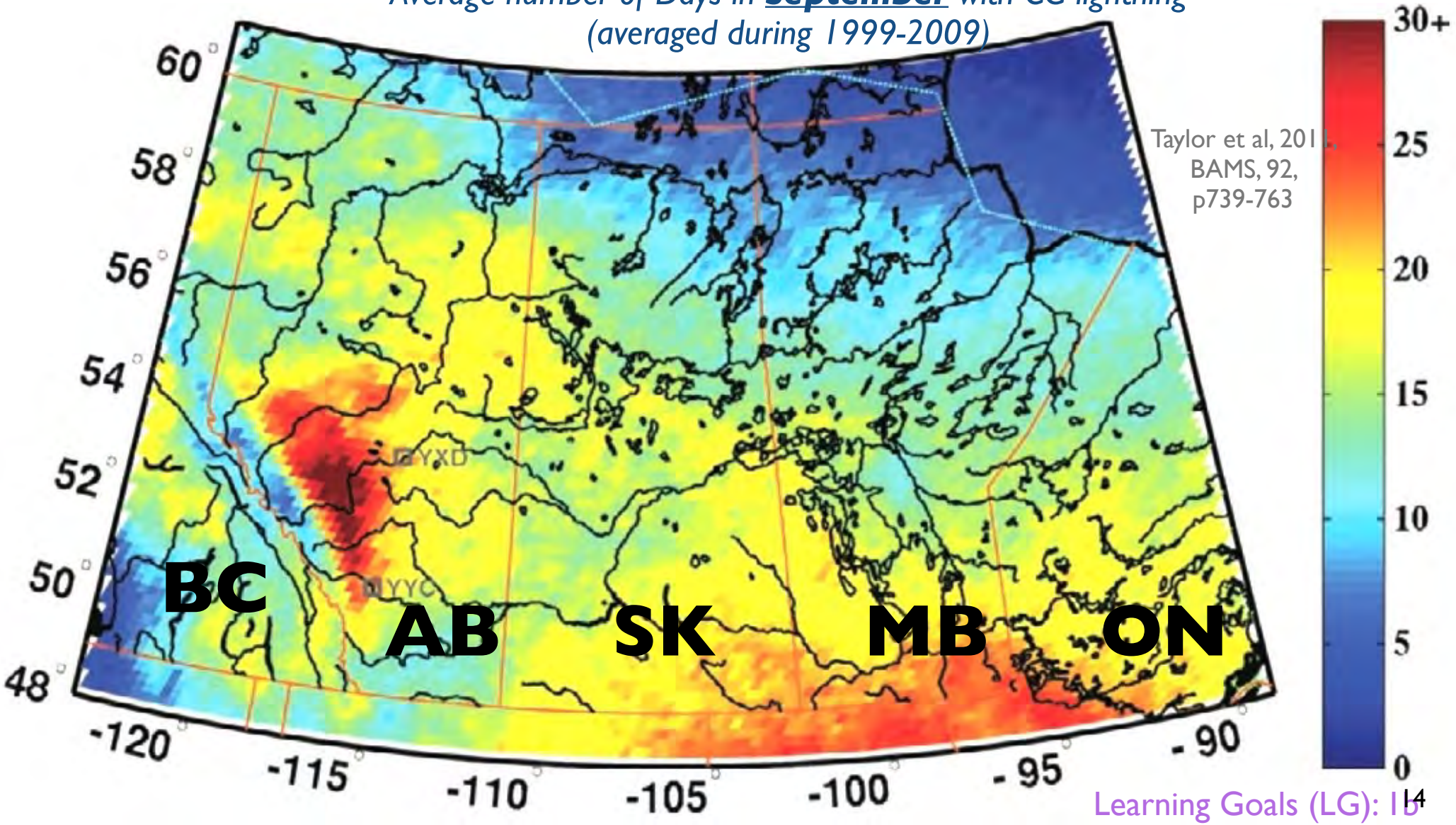


Africa has highest density of lightning worldwide![3]

*Lightning in **Canada**:*

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

*Average number of Days in **September** with CG lightning (averaged during 1999-2009)*



Taylor et al, 2011, BAMS, 92, p739-763

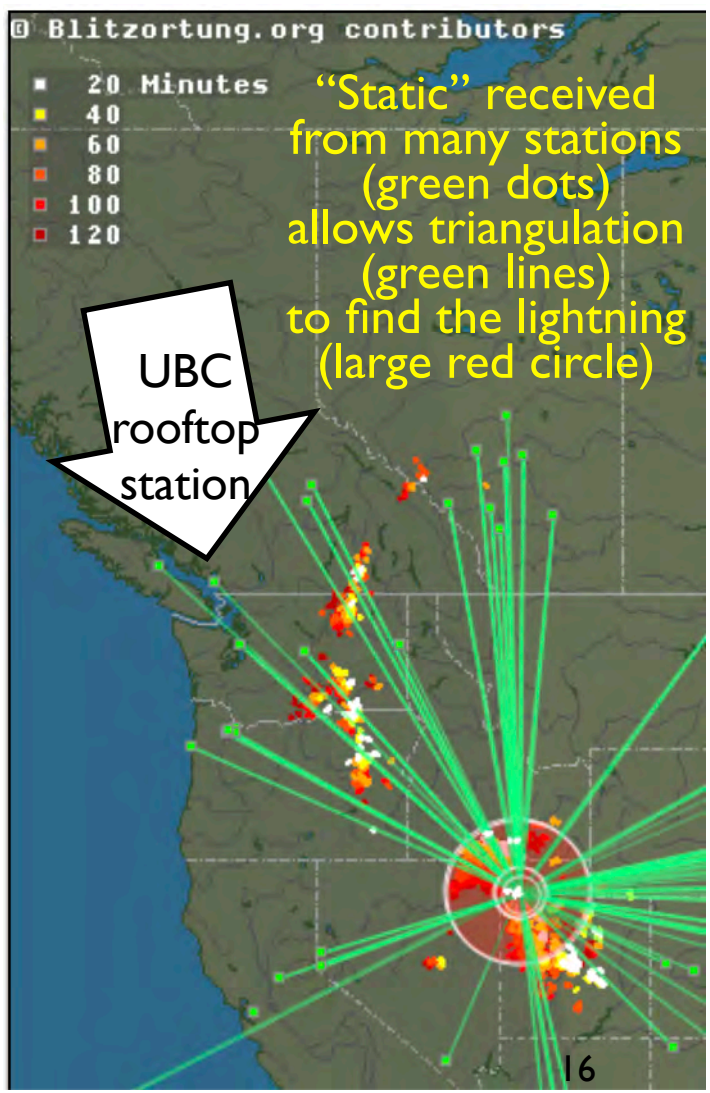
Learning Goals (LG): 1b

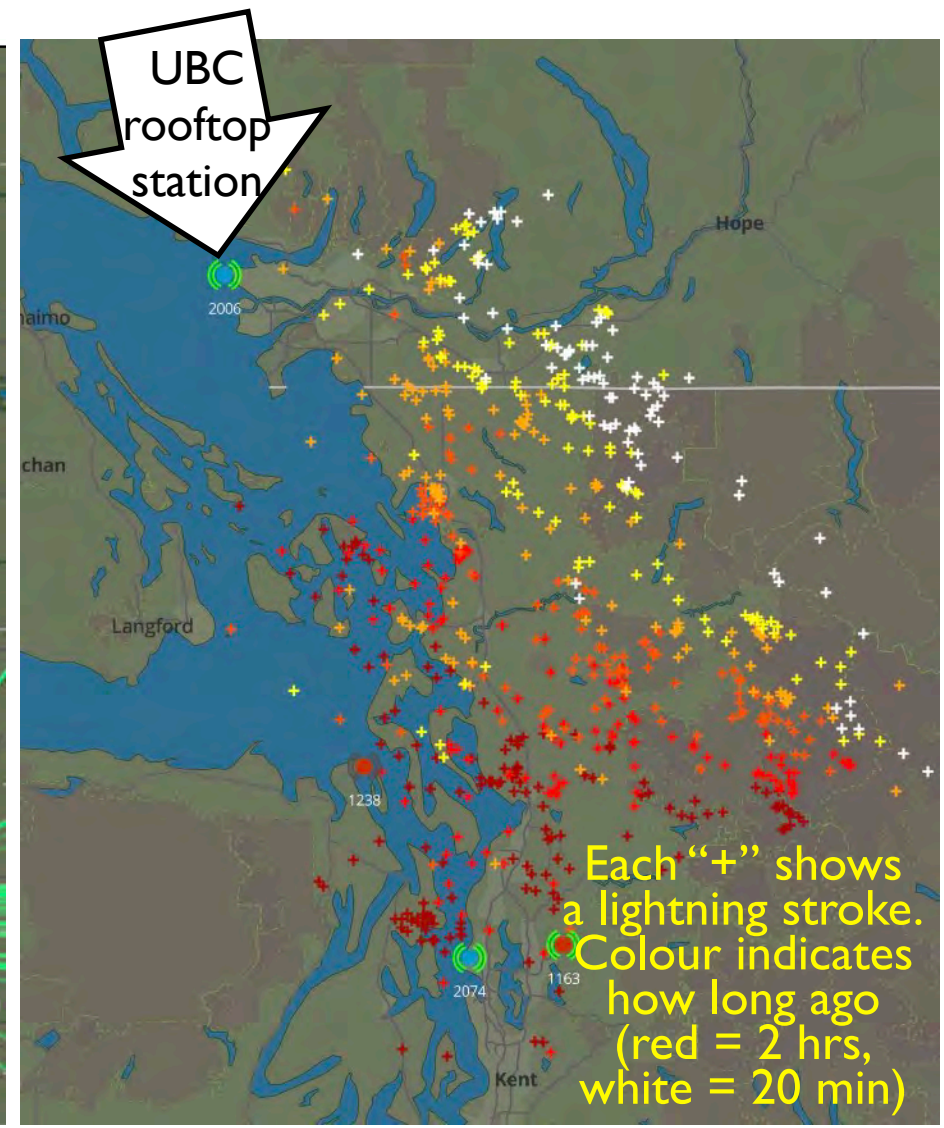
Lightning Detection Networks

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 from Space

Learning Goals (LG): 1b

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

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

How far away is lightning?

- 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 see flash and hear bang, 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 metalic 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

Just Before a Lightning Strike on a Hill Top

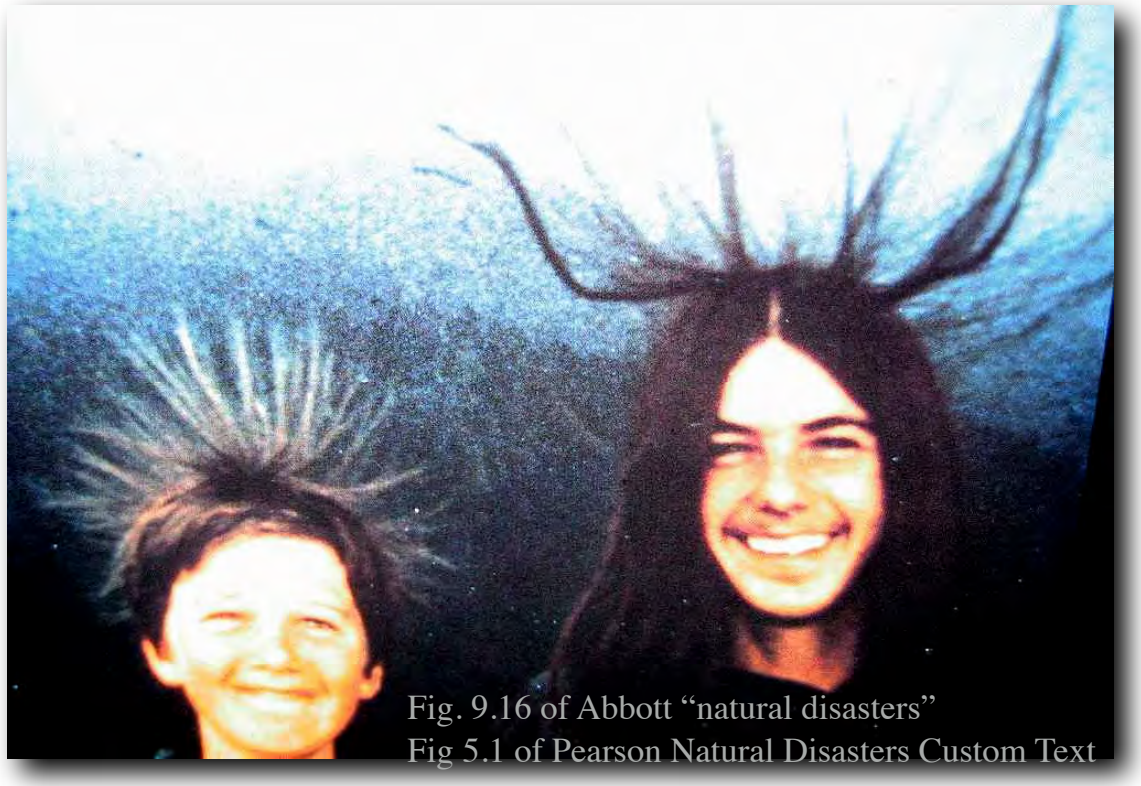


Fig. 9.16 of Abbott "natural disasters"
Fig 5.1 of Pearson Natural Disasters Custom Text

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.

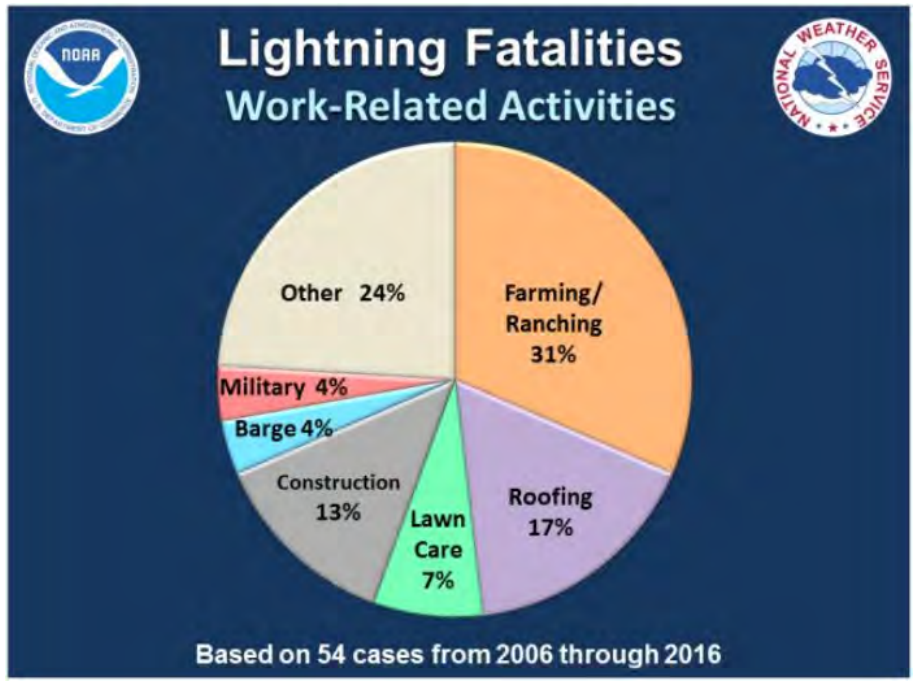
The person on the right was thrown 7 m away.

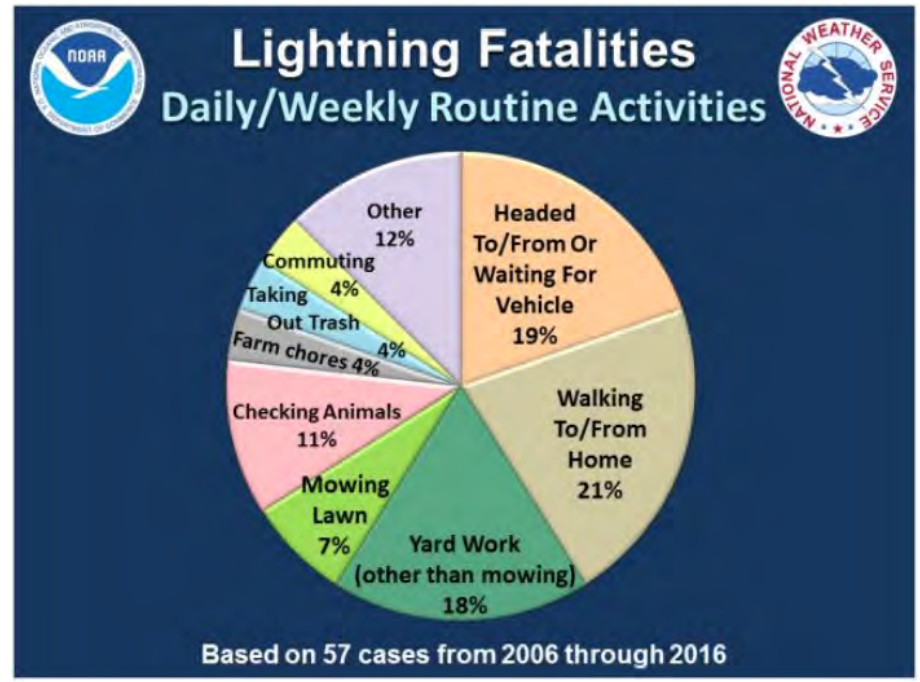
Also on that hill, one man was killed and another injured by lightning that day.

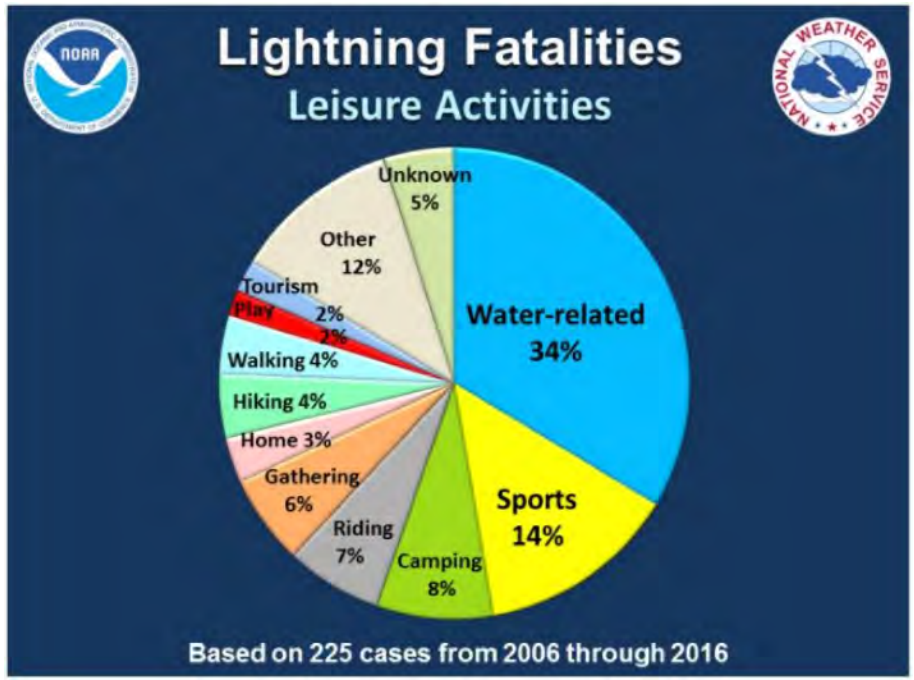
Lightning vs. Stull

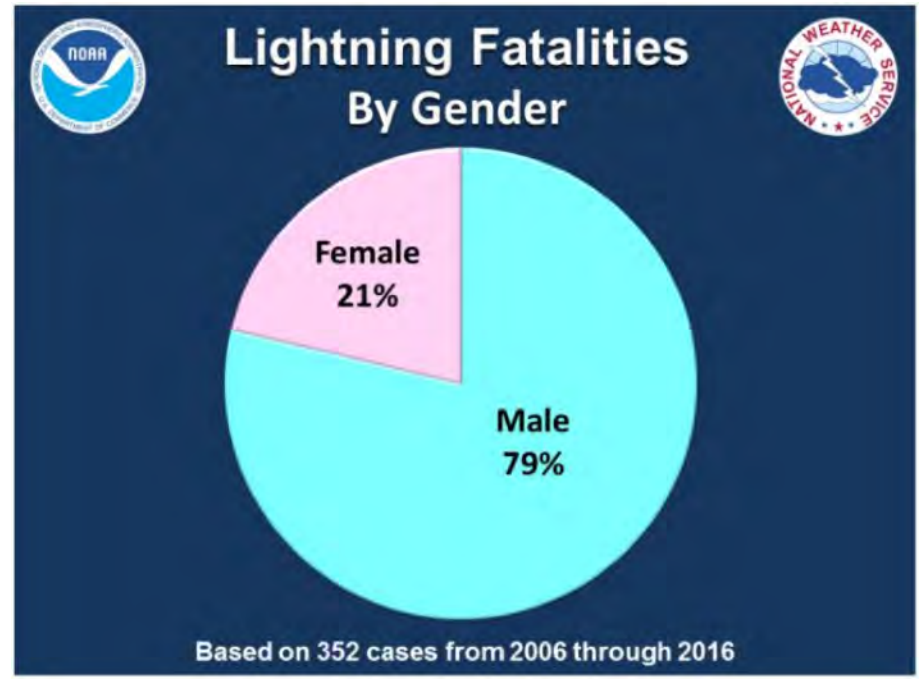
Learning Goals (LG): 1b

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

Not testable, but strikingly beautiful.

Learning Goals (LG): 1a, 1b

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=tq1mxZZIulY

Transient 3, by Dustin Farrell, 2021. More Lightning to music. (7:01)
https://www.youtube.com/watch?v=7Bxvyu2RBOw

Copies of Storm Lecture Slides

In case you are unable to view my sides via Canvas …

I put a copy of my lecture slides at

https://www.eoas.ubc.ca/courses/eosc114/

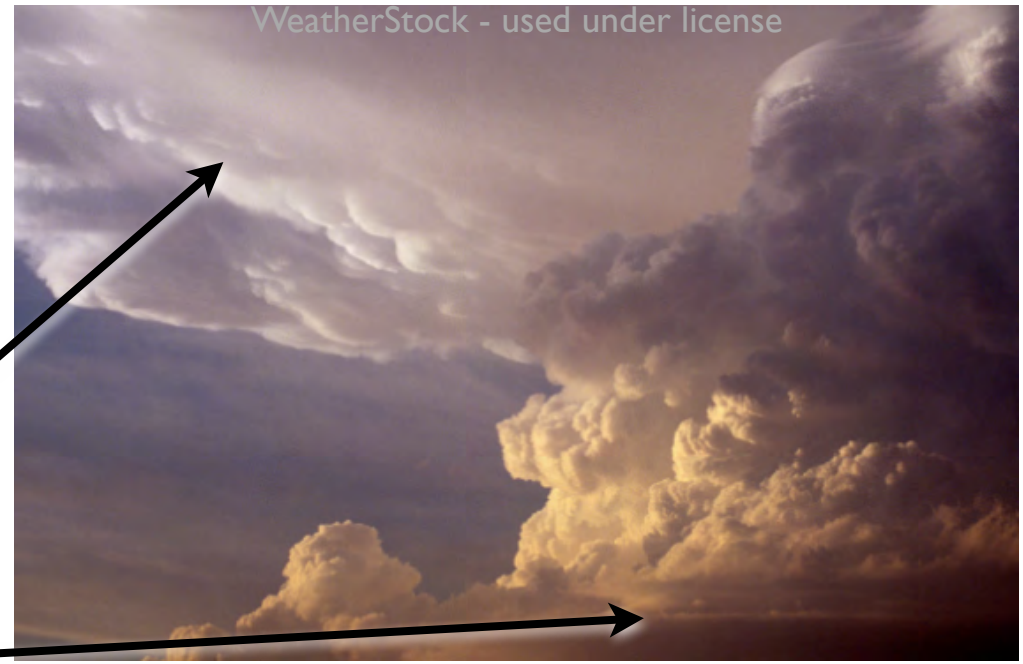
Road-map to Storm topics

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	Clouds at Tstorms: flanking line, mammatus	heat to motion, forces, winds
5	Flooding, winds, waves, storm surge	Hurricanes	energy in warm ocean, Coriolis

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 like anvil or mushroom

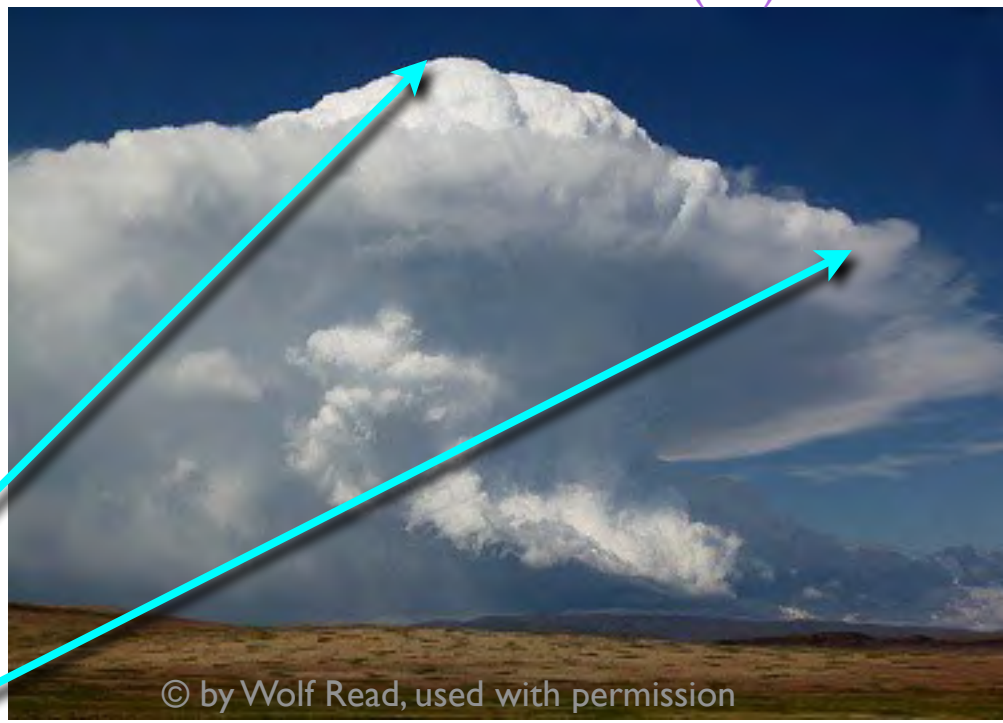
Wikipedia commons

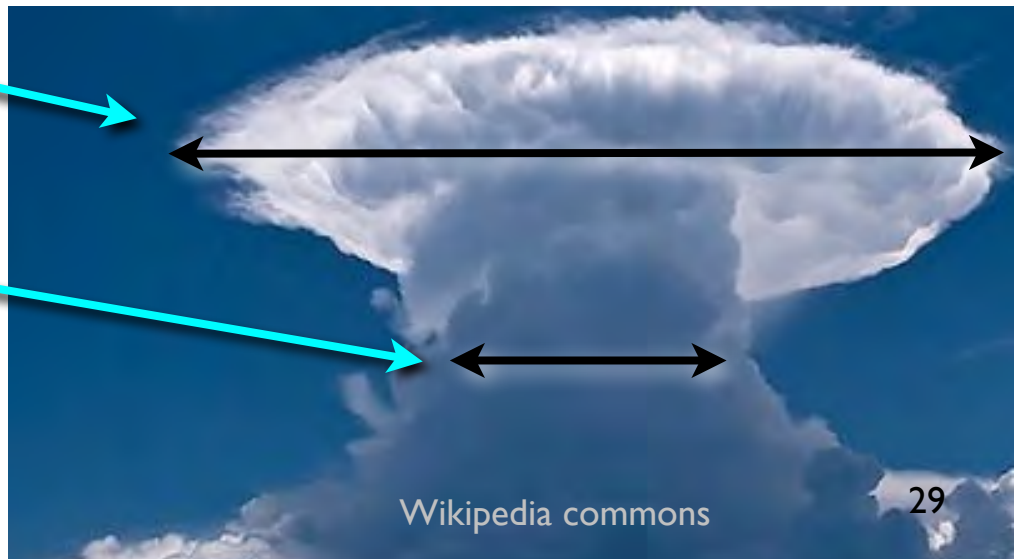
Wikipedia commons

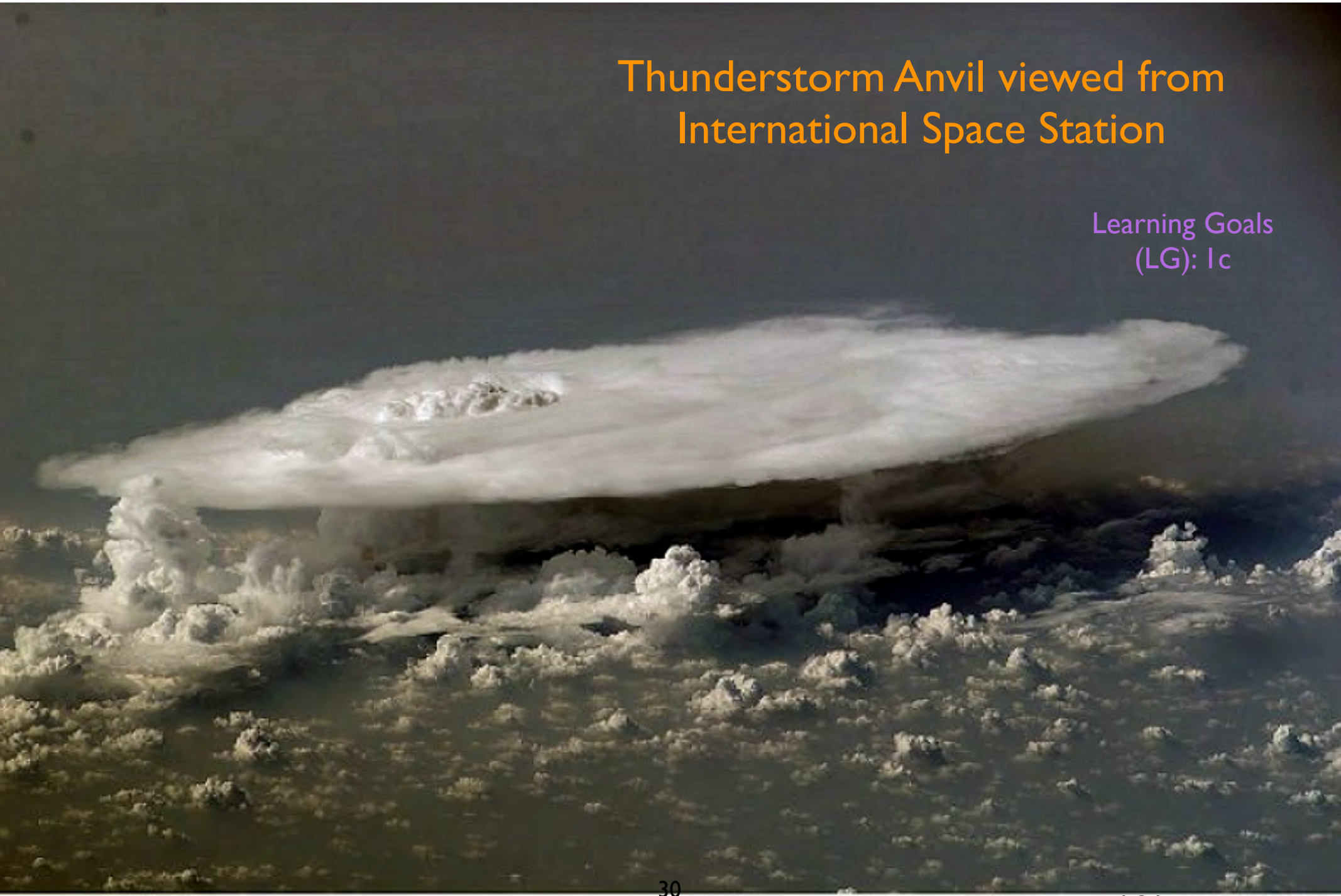
Thunderstorm Basics

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 temperature & <u>humidity.</u>







Thunderstorm Anvil viewed from International Space Station

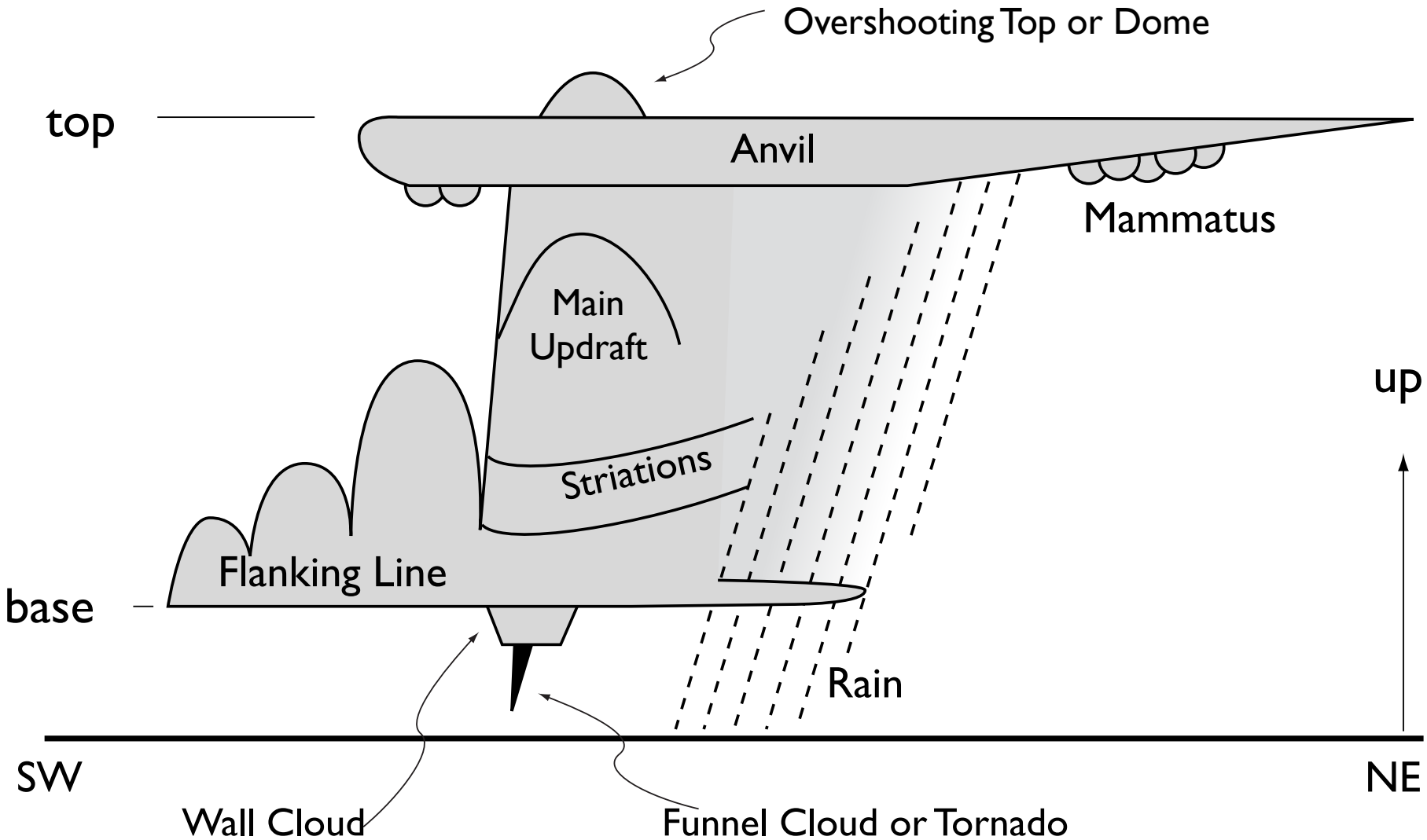
Learning Goals (LG): 1c

NASA

Thunderstorm Appearance

Thunderstorm ( ) = Cumulonimbus (CB)

Learning Goals (LG): 1c



Learning Goals
(LG): 1c

3. Thunderstorm Cells

- cumulonimbus (thunderstorms) are made of large cells that evolve during 15-30 min.
- most thunderstorms contain 2 or more cells, each indifferent stages of evolution. These are called **multicell thunderstorms**
- **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.
- Supercell types:
  low precipitation , classical , high precipitation

Today

Thunderstorm Cell Life-Cycle

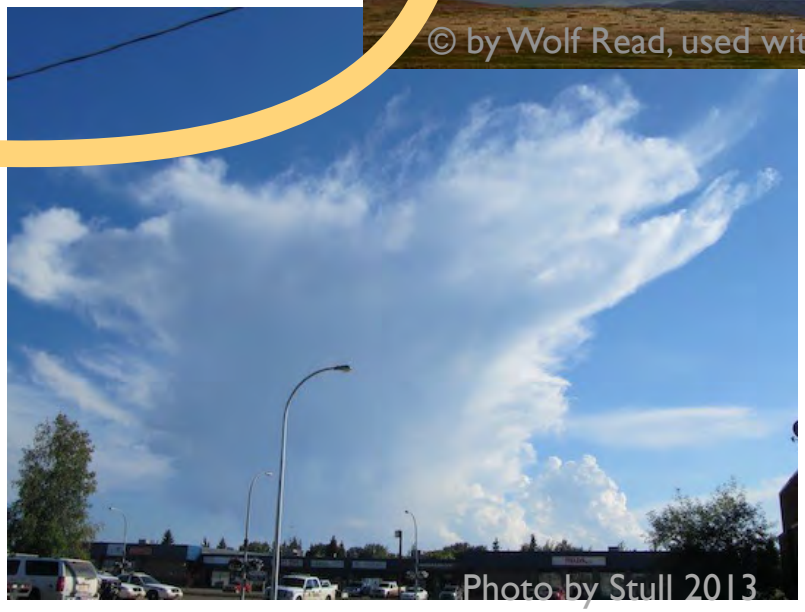
a review in photos

1) Cumulus Stage

updraft, no rain, no anvil

2) Mature Stage

up & down-drafts,
heavy rain, crisp anvil



3) Dissipating Stage

downdraft, light rain, fuzzy anvil

(The next video shows cell evolution.)

Thunderstorm Cells

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

Multicell Thunderstorm viewed from International Space Station

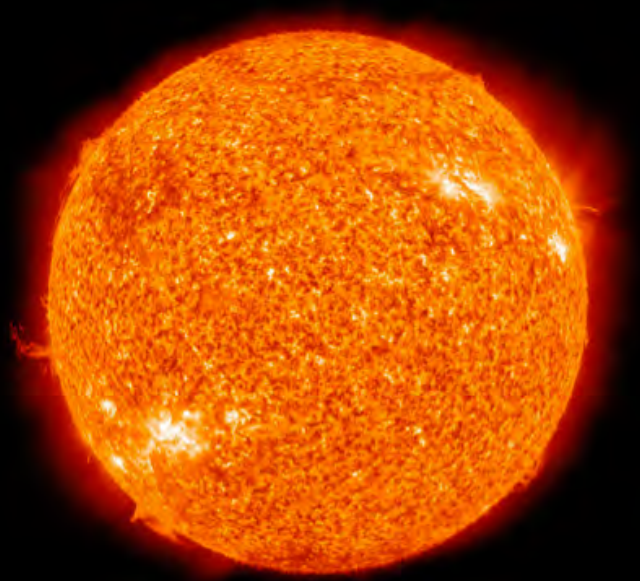
(Over Saudi Arabian desert.)

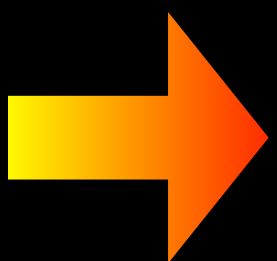
NASA

Storm Energy

A. Sun – The Source of Atmos. Heat

Learning Goals (LG): 1d





NASA

NASA

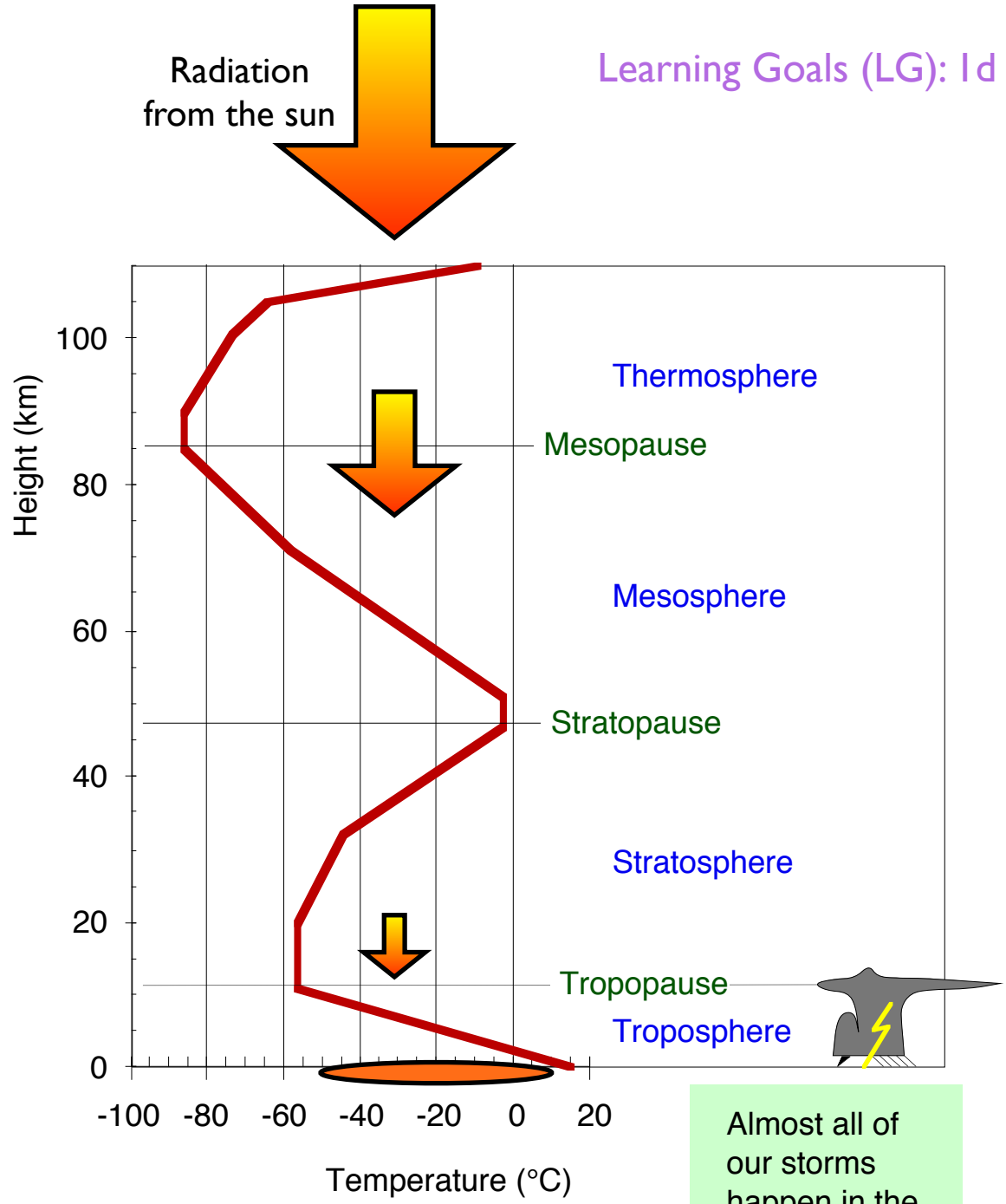
1. Solar energy is absorbed at 3 different heights:

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

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

- Bottom (earth surface). Light shines thru 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.

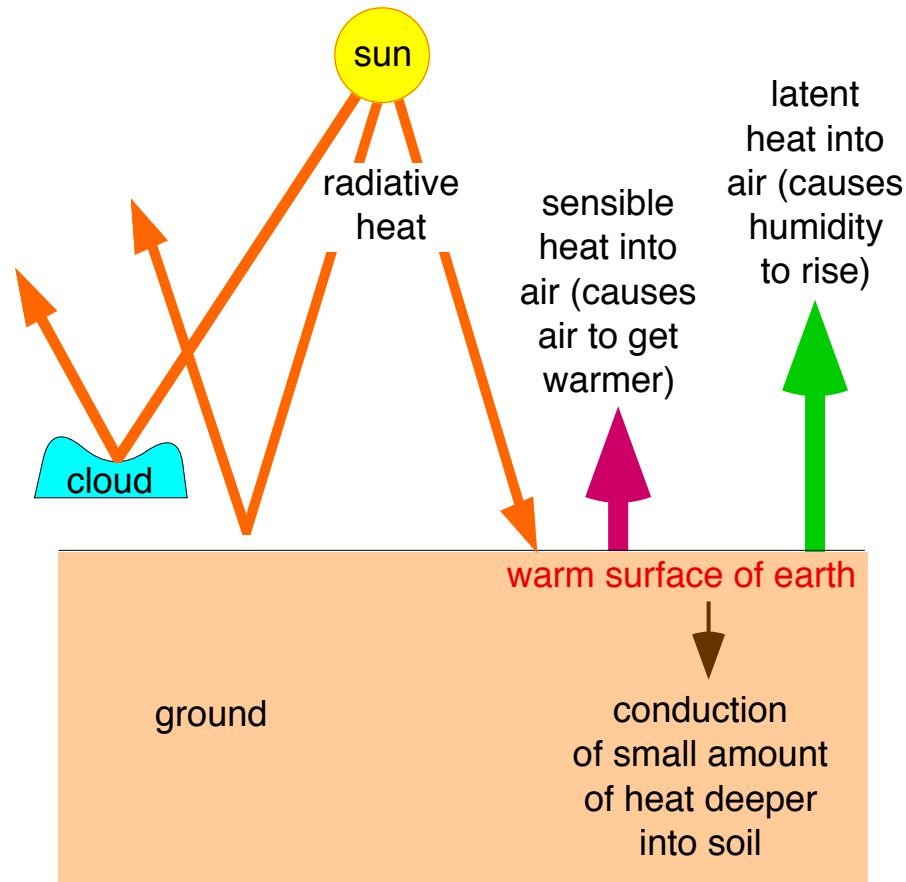


Almost all of our storms happen in the troposphere.

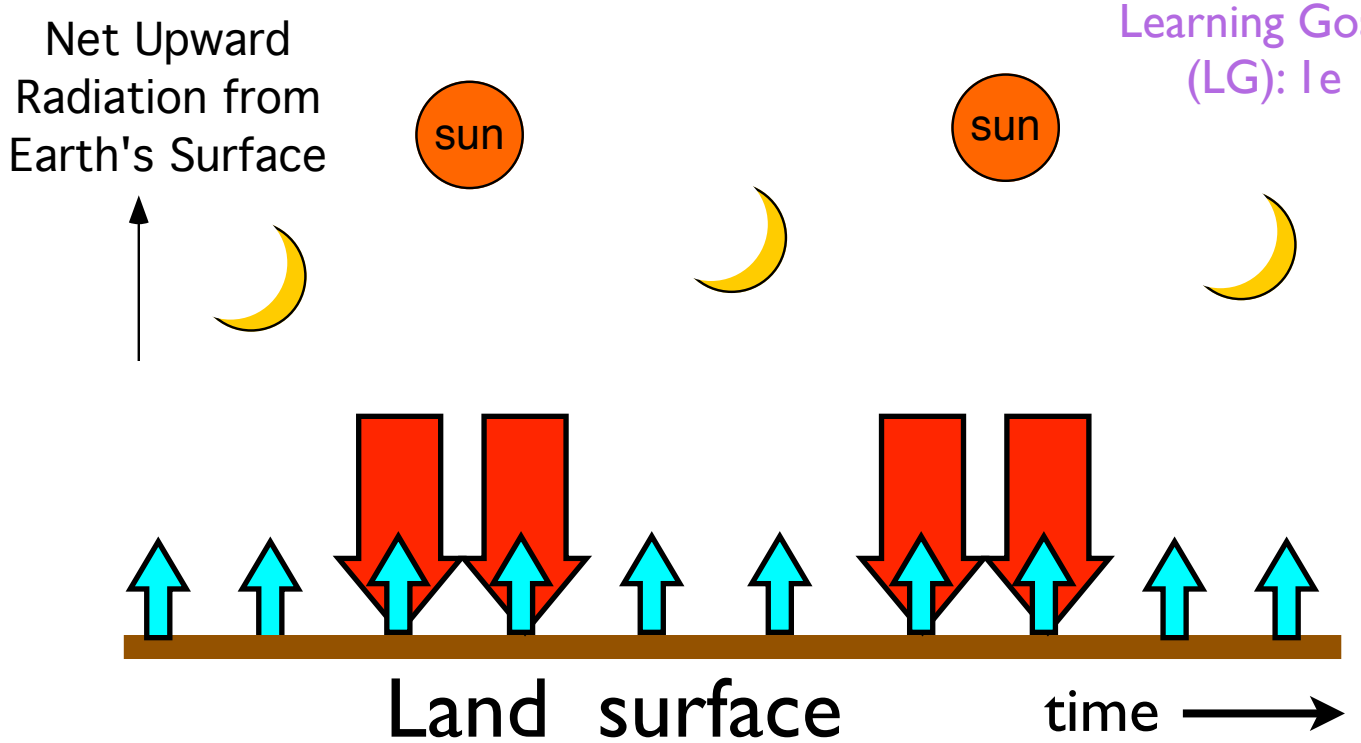
2. Surface Heat Budget

Learning Goals (LG): 1e

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



heat input to surface = sum of all heat outputs



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.

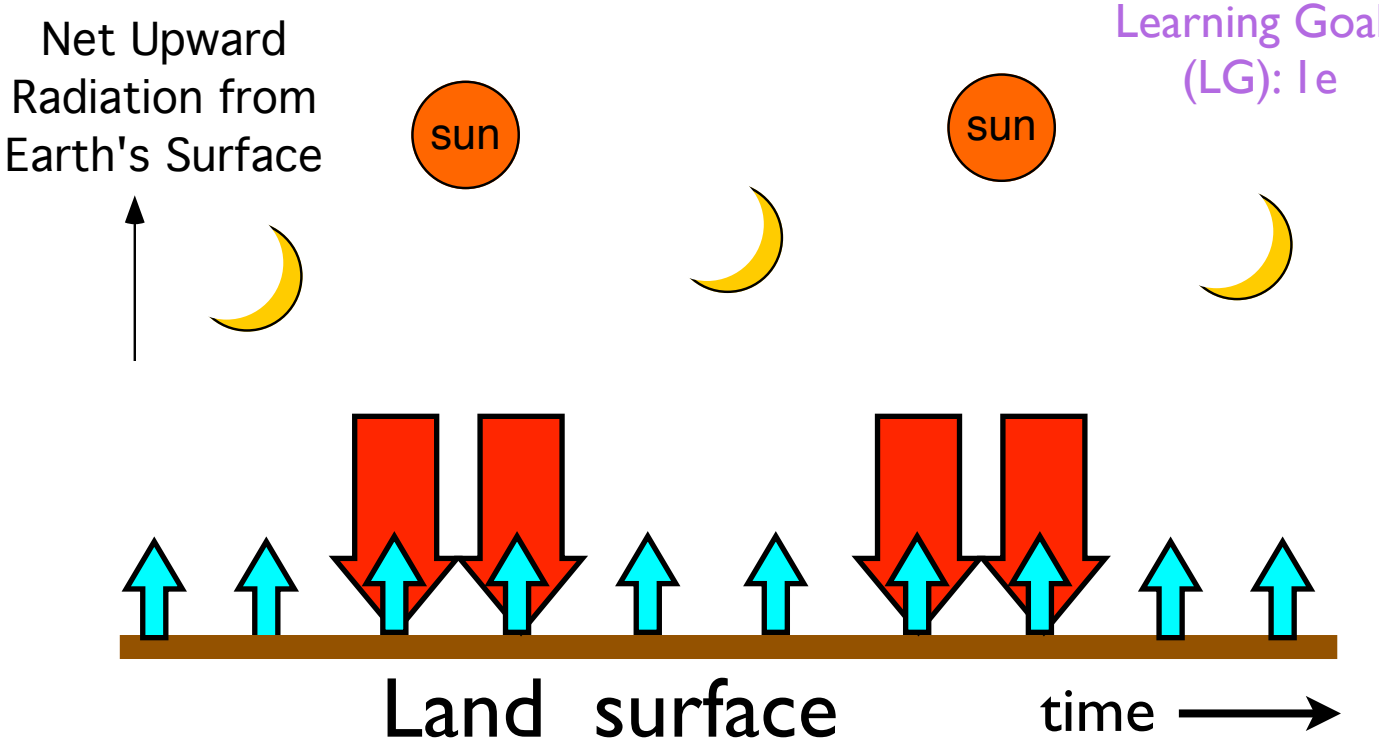
3. Daily Cycle

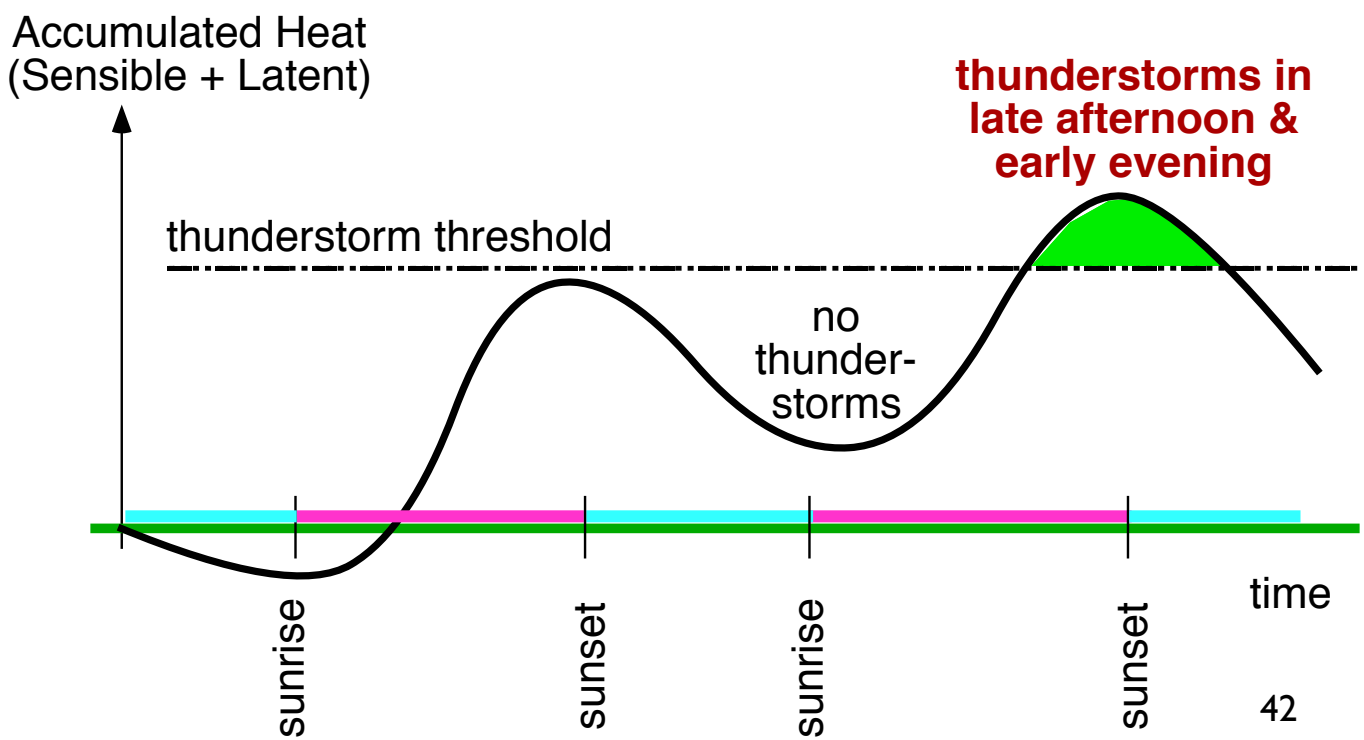
- **solar heating** during day => **input** (like charging a battery)

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

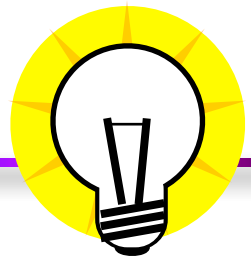
- ==> greatest **accumulation of heat**, near sunset every day (at end of each charging cycle) .

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





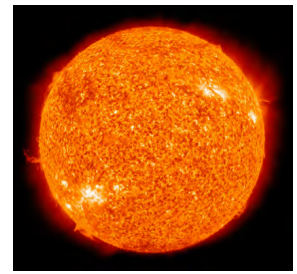
Insights



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.



NASA

Which statement is TRUE?

(A) the earth's surface loses energy day and night due to infrared radiation.

(B) all sunlight reaching the earth's surface warms it.

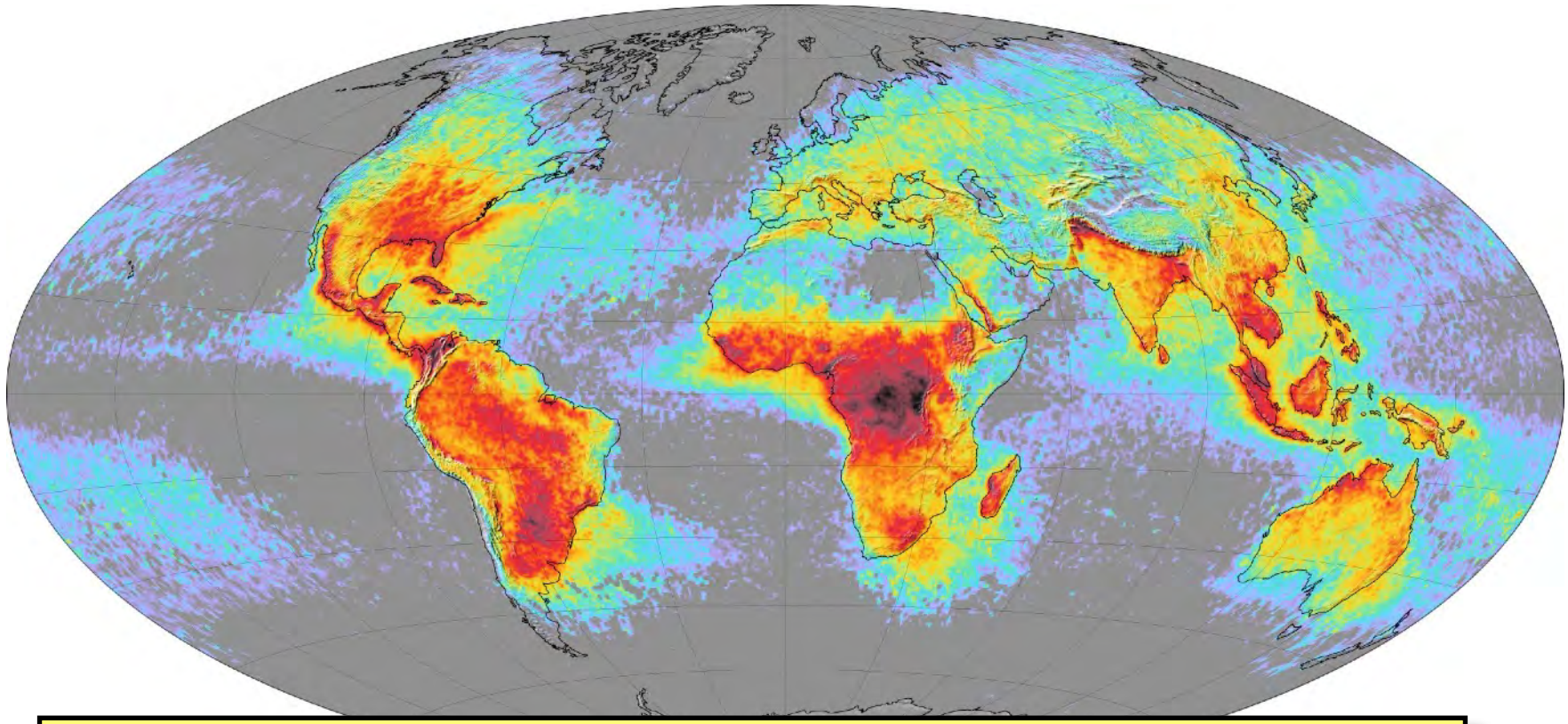
(C) the time of day having the greatest rate of solar-energy input is near noon.

(D) the time of day when most heat is accumulated is near sunset.

(E) thunderstorms are most likely near noon, when the sun is highest in the sky.

4. Thunderstorm Locations

Learning Goals (LG): 1e



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)

The Turbulent Atmosphere

Prof. Roland Stull

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

Learning Goals (LG): 1a-e

Next Class

- Supercell thunderstorms & mesocyclones
- Hail and Rain
- Storm Energy

  B. Humidity – the fuel for storms