EOSC 114 - Storms

LG 2a-d

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

Day 2 - Video 00 - Monsoon IV. (8:08) (not testable):

video by Mike Olbinski
https://www.youtube.com/watch?v=LbY3DdzV0rA

Other YouTube Videos you can watch on your own. (not testable):

Day 2-01 Time-lapse of 2015 supercell storm chase.
(5.5 minutes) play at fast speed

https://www.youtube.com/watch?v=U9m9XVmfrxU

Day 2-05 Time-lapse of thunderstorm evolution & lightning 2015 (3.75 minutes, Pecos Hank) play first half at normal speed; 2nd half play faster

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

The Turbulent Atmosphere (Storms)

Instructor: Doug McCollor
Fri Sept 13, 2024

Outline for Today

- More Thunderstorm Fundamentals
  - Observing Tstorms, with satellite & radar
  - Squall-line thunderstorms
  - Supercell thunderstorms & mesocyclones

- Thunderstorm Hazards:
  downpours of rain &
  downbursts of air

- Storms Energy part B. Moist air – the fuel for storms

Today's Learning Goals (LG: 2a-e)

By the end of this period, you should be able to:

2a) use images and videos from weather radars (reflectivity & Doppler velocity) and satellites (visible & infrared) to identify storm characteristics and anticipate storm changes.

2b) name and describe the characteristics and hazards of squall lines and of the 3 main types of supercell thunderstorm.

2c) identify mammatus clouds, cloud striations, virga, haboobs, arc clouds, and explain their significance

2d) identify downbursts and gust fronts, describe how they form and look, and their hazards

2e) explain how humidity, saturation, latent heat, advection, and adiabatic cooling affect storm energy.

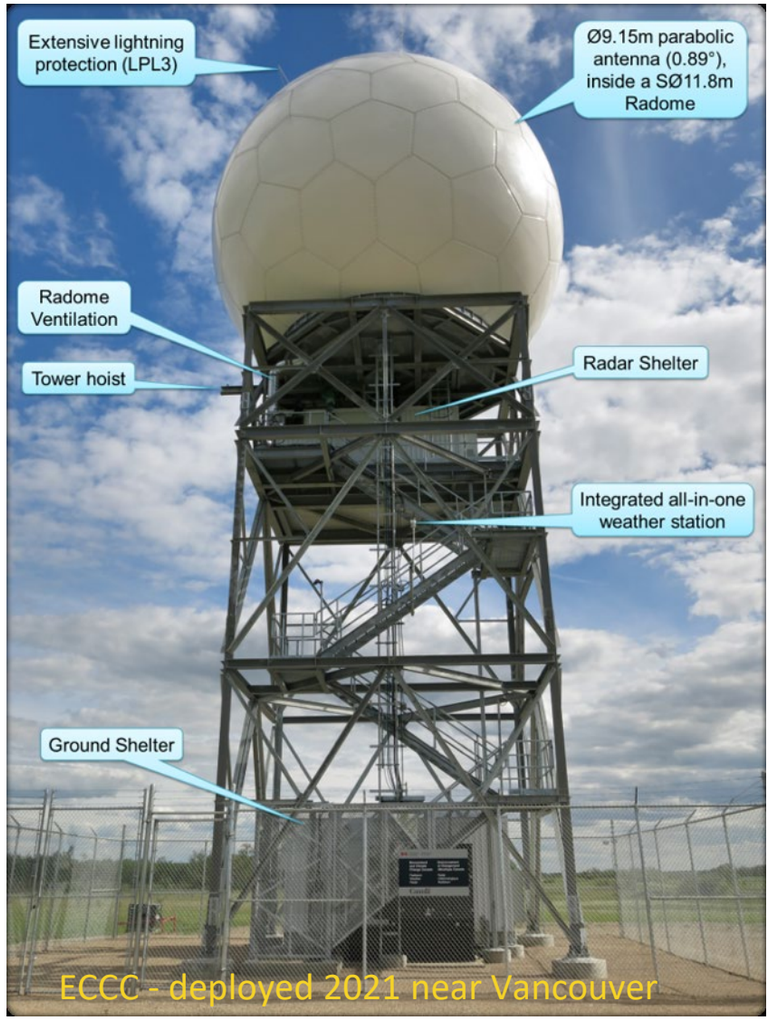
Road-map to Storm topics

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

Observing and Monitoring using Remote Sensors

Radar



Satellite

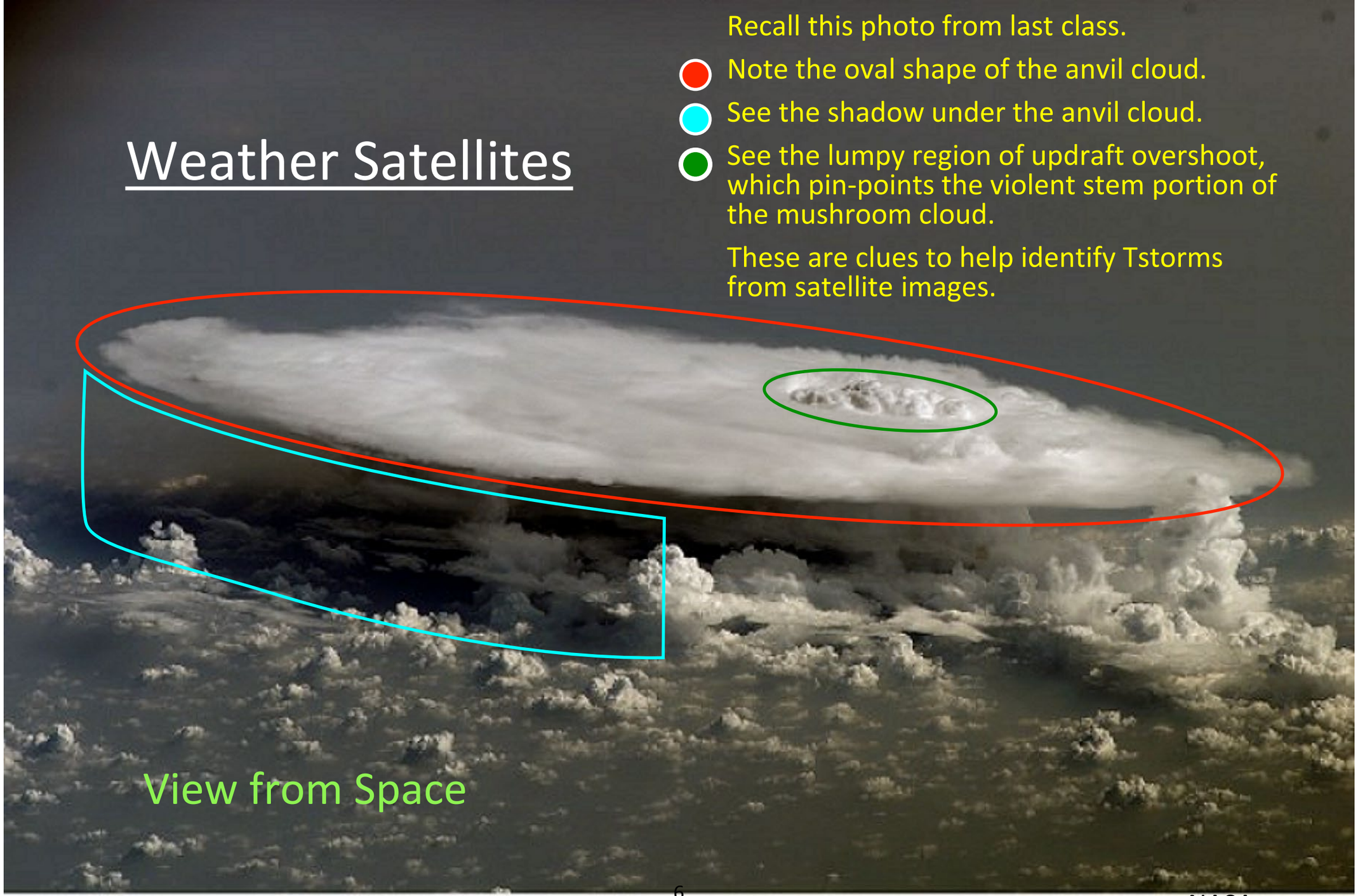
A remote sensor is an instrument that is remote from (outside of) the storm, but can still measure the storm.

Weather Satellites

Recall this photo from last class.

- Note the oval shape of the anvil cloud.
- See the shadow under the anvil cloud.
- See the lumpy region of updraft overshoot, which pin-points the violent stem portion of the mushroom cloud.

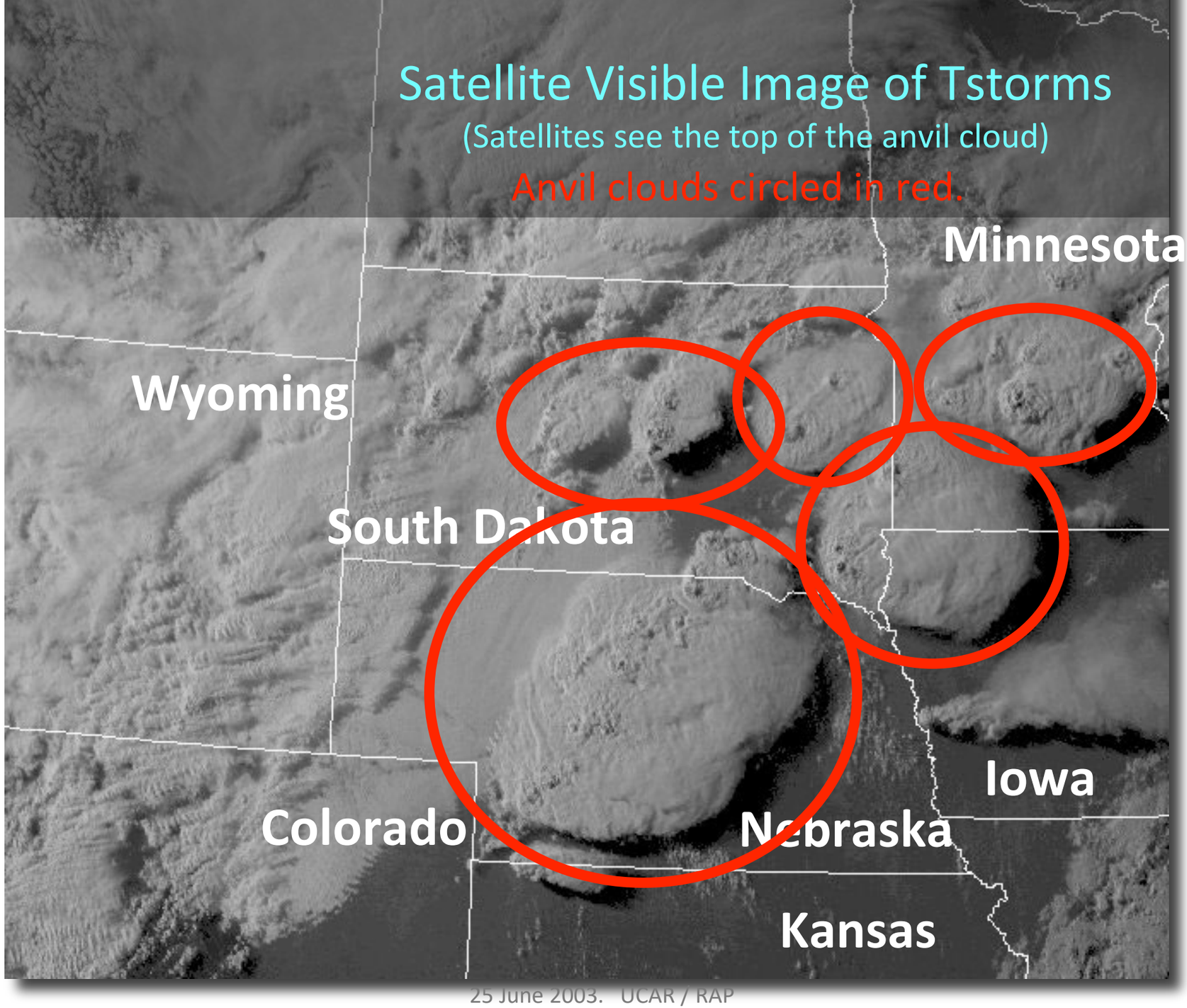
These are clues to help identify Tstorms from satellite images.



View from Space

ISS016E027426

NASA

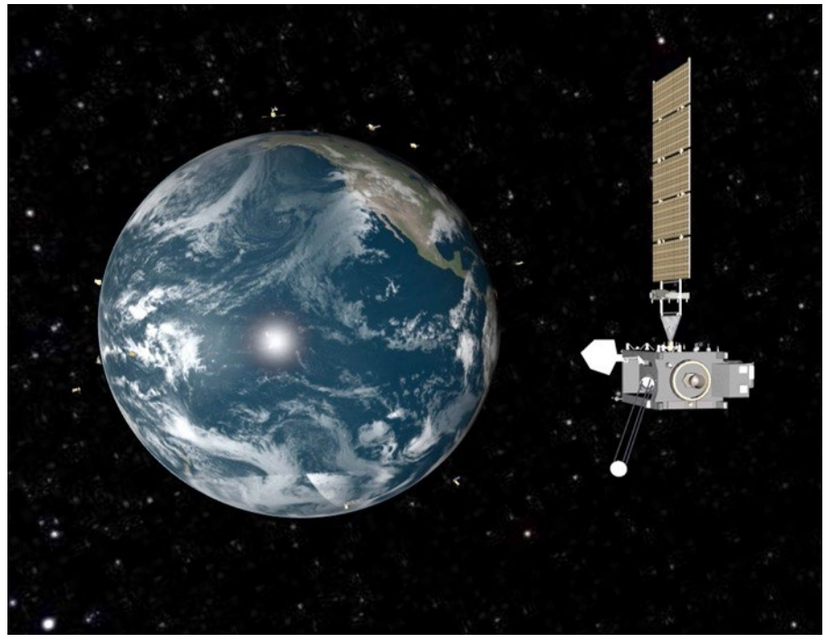

Satellite Visible Image of Tstorms
(Satellites see the top of the anvil cloud)
Anvil clouds circled in red.
Minnesota
Wyoming
South Dakota
Iowa
Colorado
Nebraska
Kansas

Thunderstorms observed from Space

LG 2a

Thunderheads near Borneo, Indonesia are featured in this image photographed by an Expedition 40 crew member on the International Space Station. Credit: M. Justin Wilkinson, Jacobs and Michael

Satellite Videos of Thunderstorm Growth & Hurricane Evolution from new GOES 16,17 & 18 Satellites



Day 2 Video 34:

Satellite visible time-lapse of a 2017 Thunderstorm evolution (0:41) CIMSS:

https://www.youtube.com/watch?v=XDmtbHet8n0

Visible images show clouds during daytime only.
IR images can show clouds both day and night.

Day 2 Video 33 (view in web browser):

Satellite visible & IR time-lapse of (2019) Hurricane Dorian evolution (1:00):

https://cimss.ssec.wisc.edu/satellite-blog/wp-content/uploads/sites/5/2019/09/190901_goes16_visible_infrared_30second_Dorian_anim.gif

IR = infrared.
High altitude clouds are highlighted in red, because these are often the tops of dangerous thunderstorms

Weather Radars

Photos: Anthony Di Stefano

Environment & Climate Change Canada (ECCC)

has been deploying new weather radars across Canada for the past 4 years.

Video: Day 2-XY on ECCC radars. (2:00)

https://www.youtube.com/watch?v=qhXj3s9qwTE

Vancouver got their new radar in 2021, replacing the old one near Aldergrove, BC.

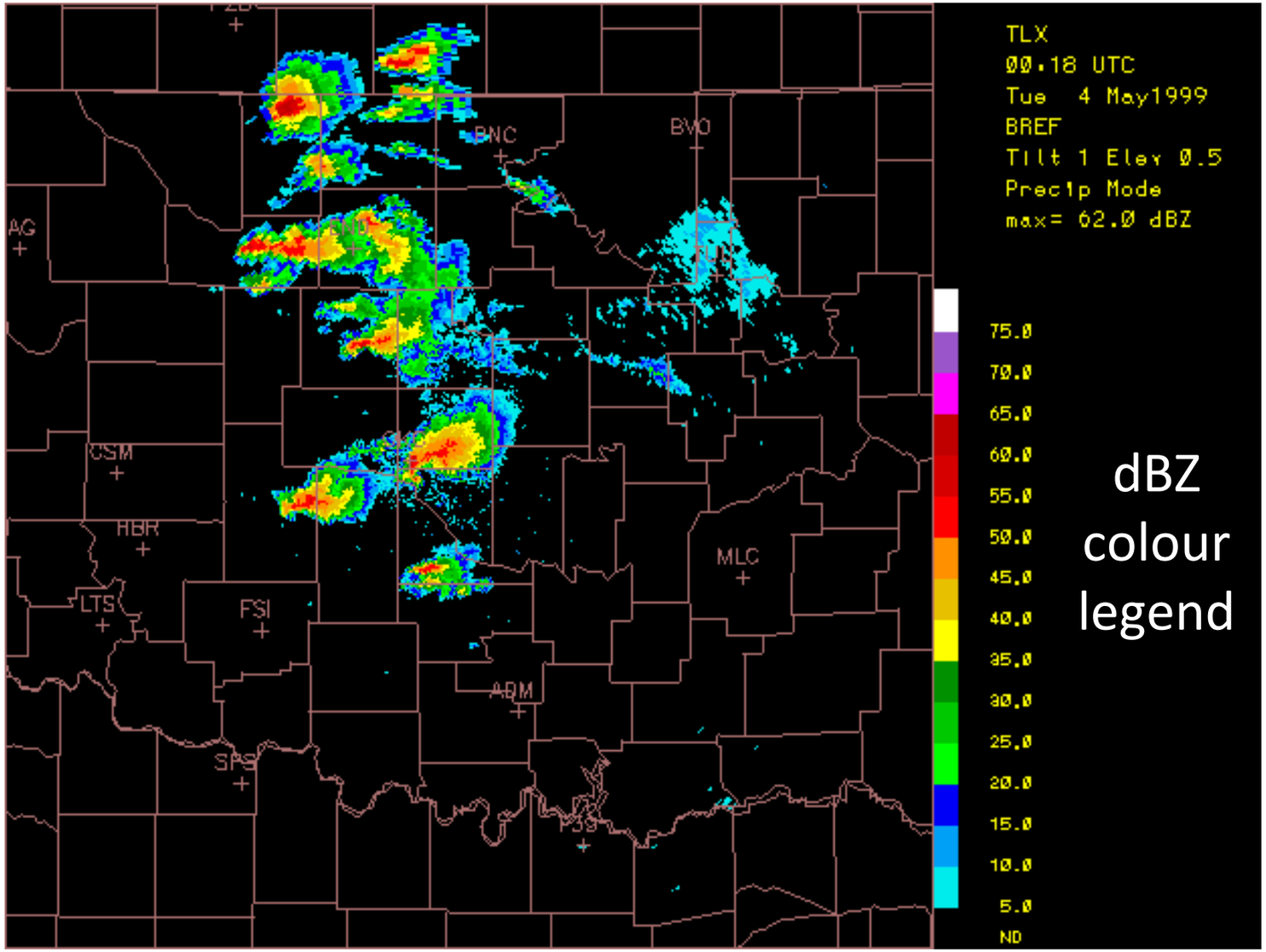
Another radar is now located on the Sunshine Coast.

Radar Image of Thunderstorm Cells

(radar sees the precipitation inside the storm; namely, in the up- & downdraft stem of the mushroom cloud)

Radar

Tornado Outbreak in Oklahoma, (3 May 1999)

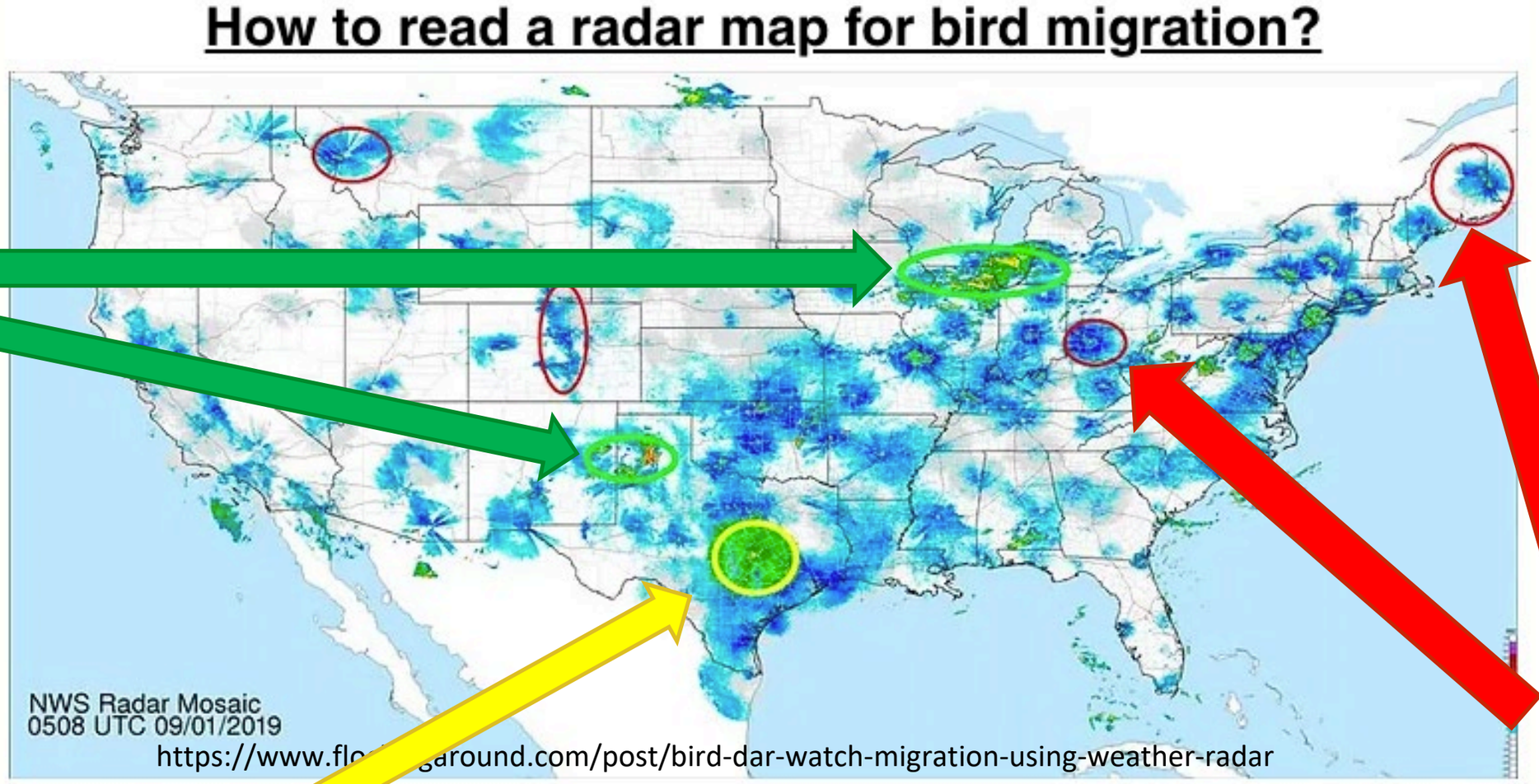


from NWS

What else might radar pick up on?

radar microwaves reflect off anything in the atmosphere – rain, hail, snow, or…?

Radar



Storms

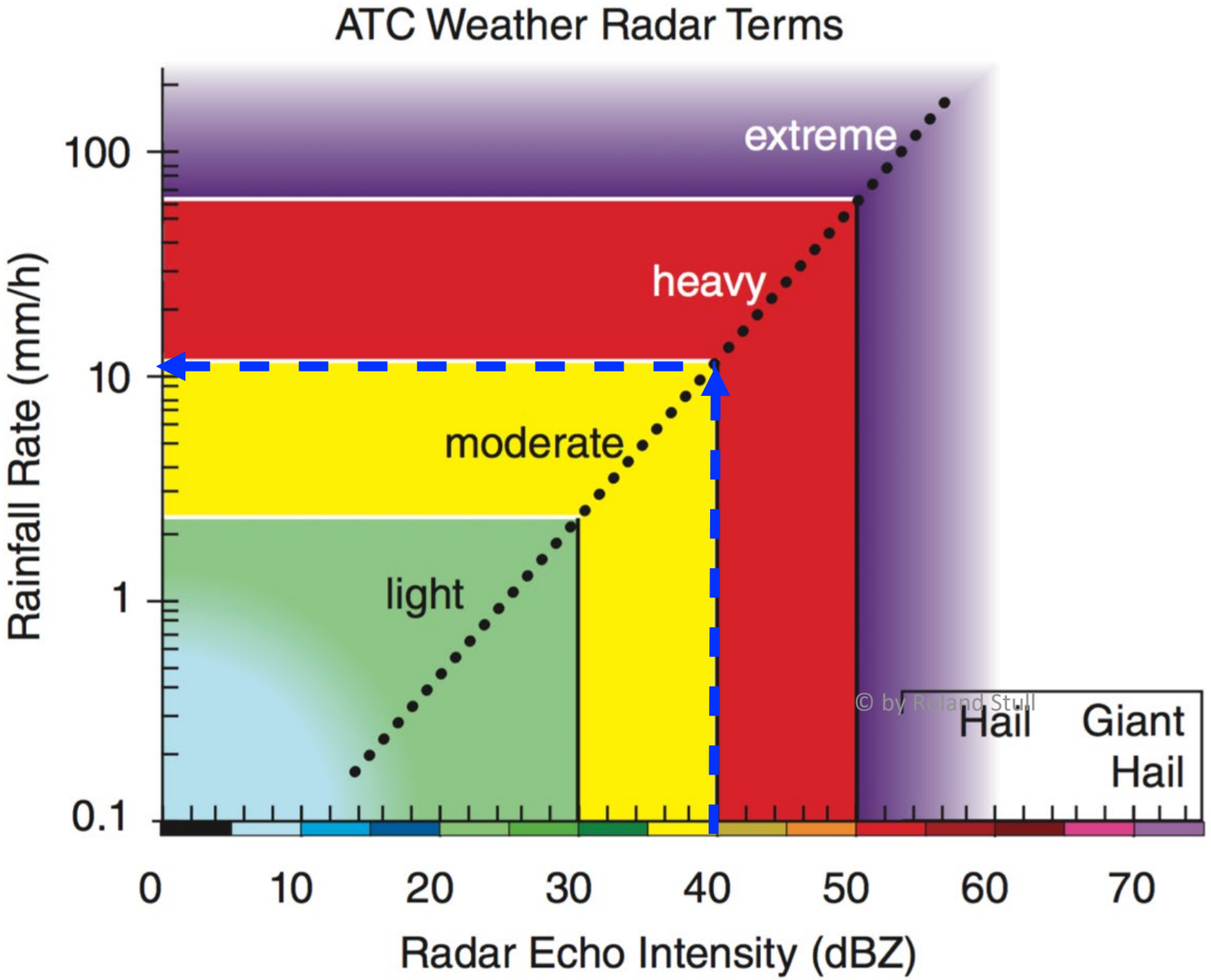
Birds!

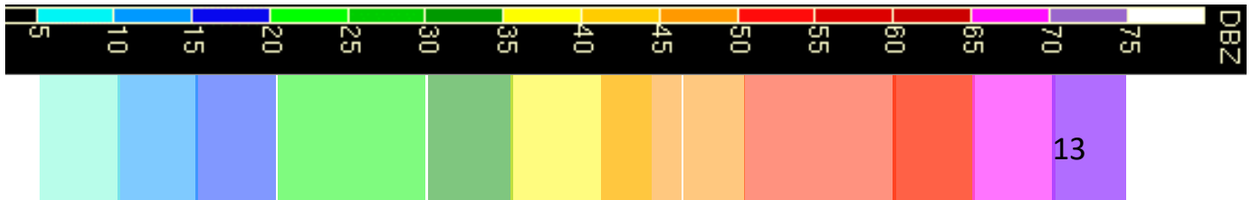
likely a combination of birds, insects, and A LOT of bats

from NWS

dBZ:
A Disaster Intensity Scale for Radar-echo Strength

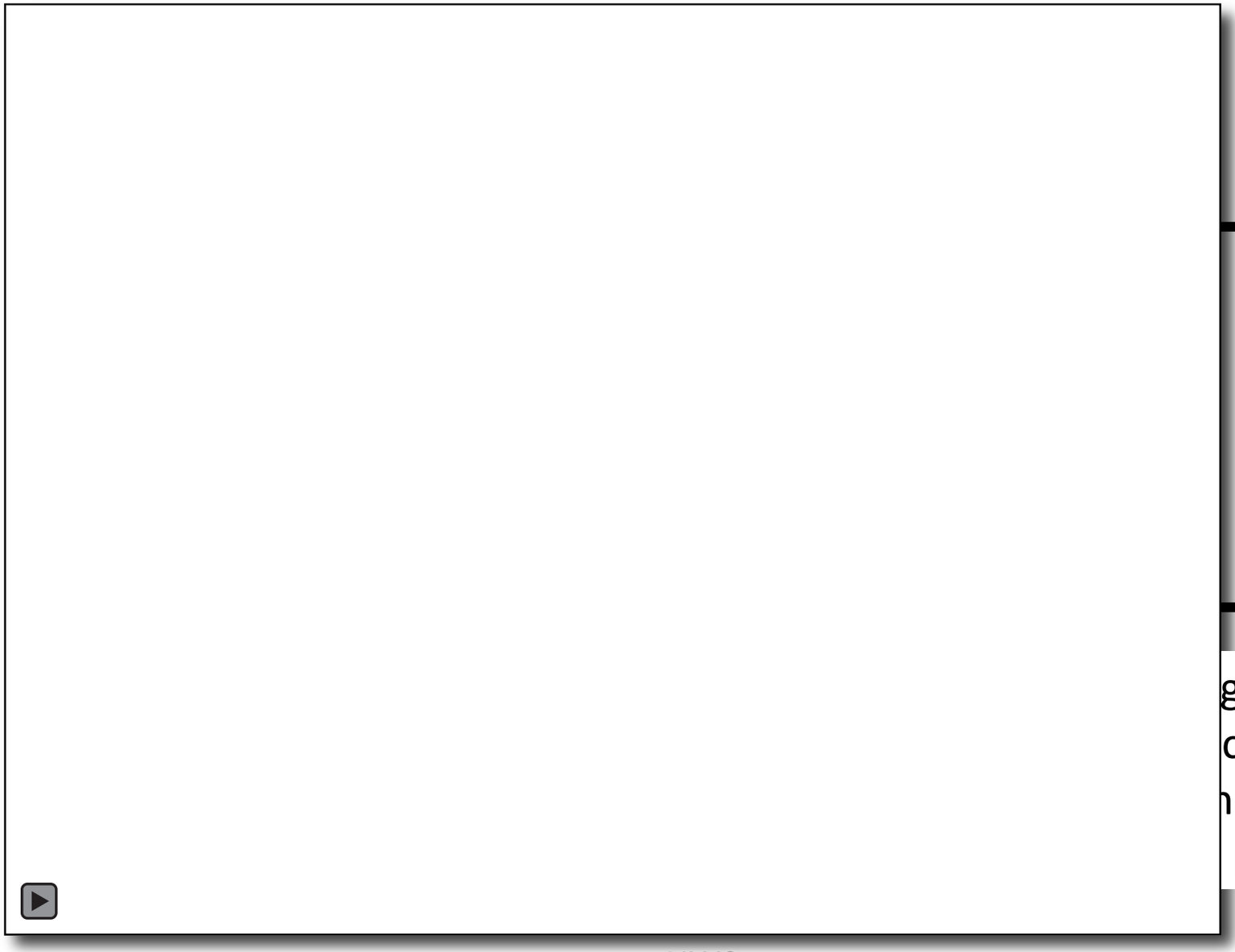
(an indicator of Rainfall-Rate)





dBZ = radar echo intensity (in decibals).

Radar Loop (video) of Thunderstorms



dBZ

g past movement
cells on radar, we
n people in their
paths.

NWS

Weather Radar Damaged by winds in Hurricane Irma 2017

Thunderstorm Cells : Squall lines & Supercells

- cumulonimbus (thunderstorms) are made of large cells that evolve during 15-45 min.
- most thunderstorms contain 2 or more cells, each in different stages of evolution. These are called **multicell thunderstorms**

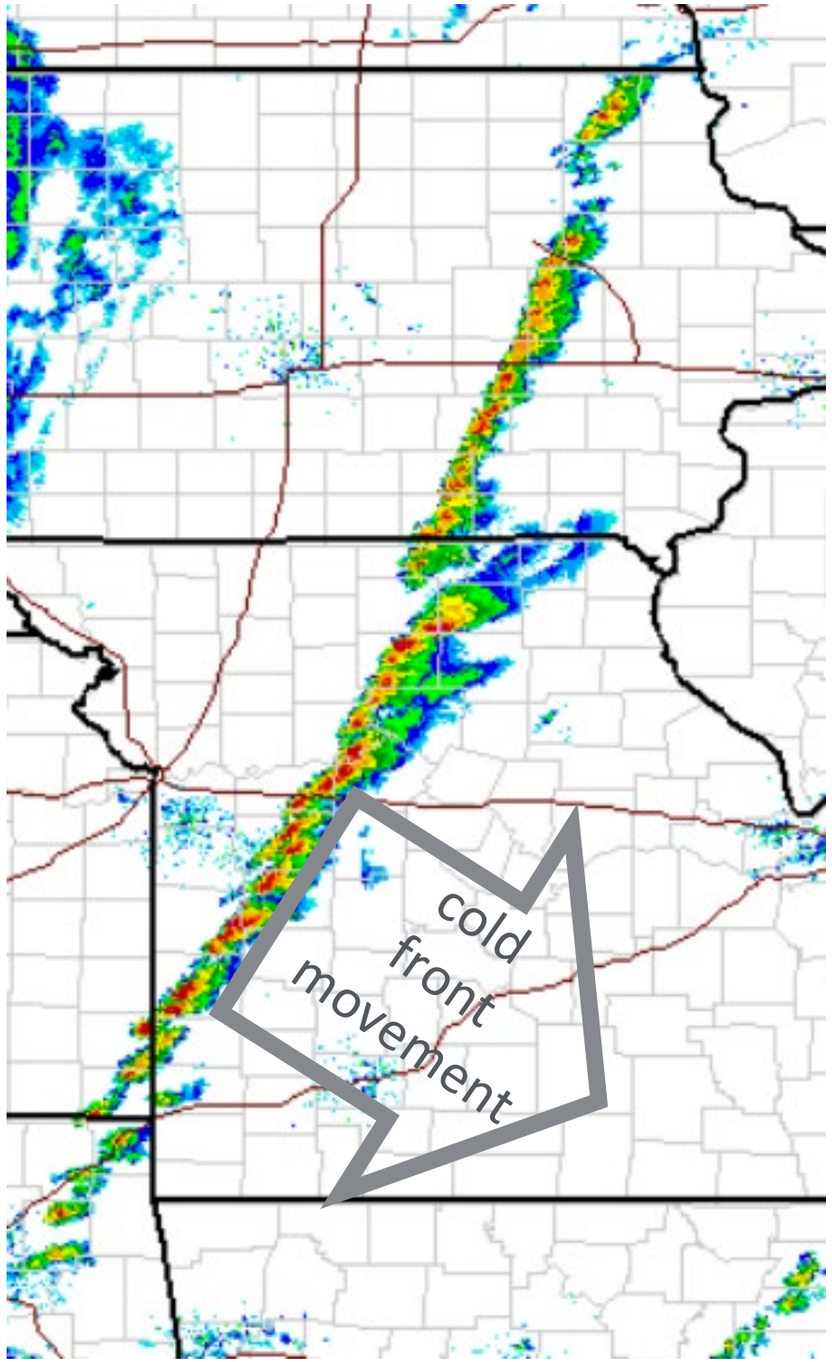
Last class

- **squall line** - a line of thunderstorms
- sometimes a very large, rotating single-cell thunderstorm forms, called a **supercell** thunderstorm. They can cause the most violent tornadoes, large hail, frequent lightning, heavy rain, strong winds. A rotating thunderstorm is called a **mesocyclone**.
- Supercell types:
  low precipitation, classical, high precipitation

Now

Squall Line Thunderstorms

- Consists of many thunderstorms in a line; hence, these storms are “linear”, or somewhat-linear (“quasi-linear").
- Often form along a cold front.



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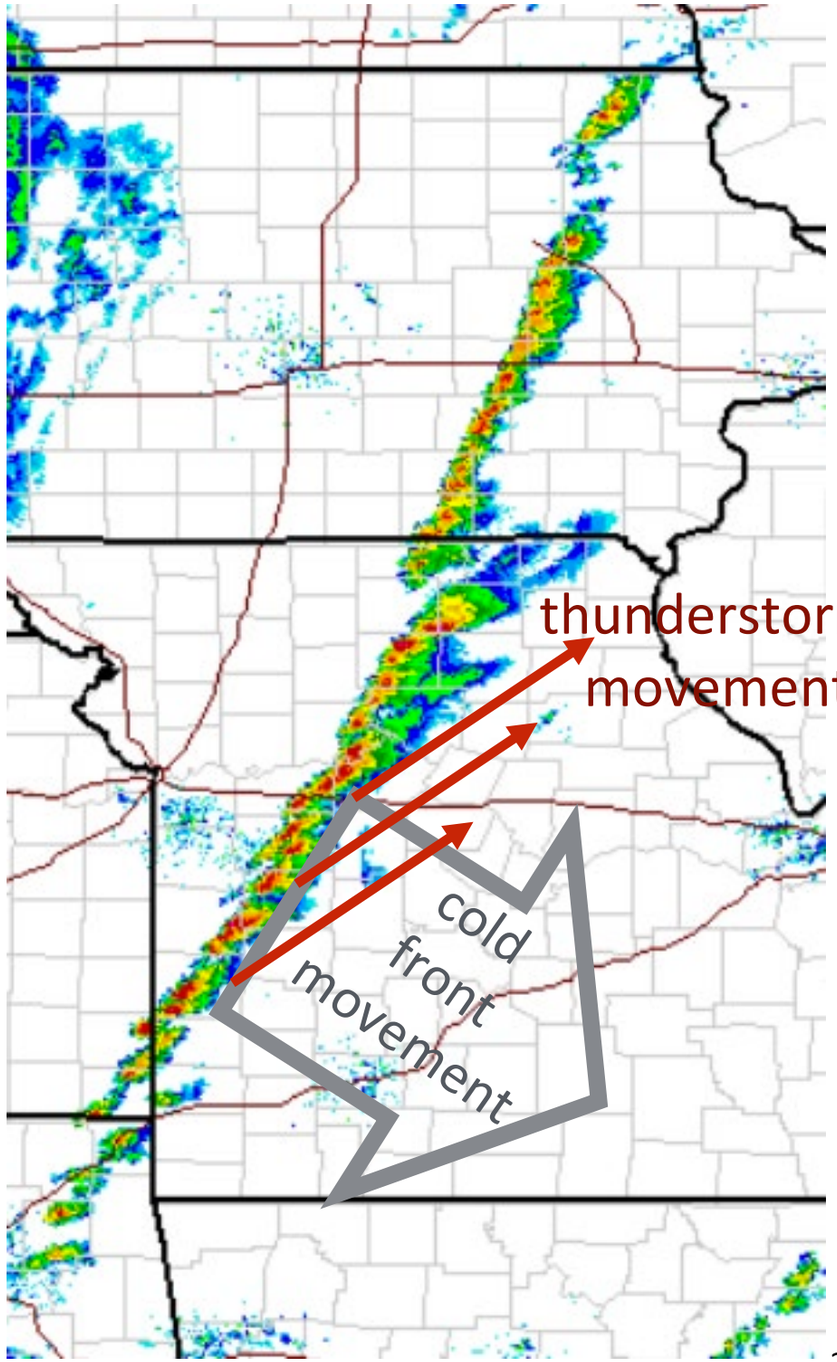

Squall Line Thunderstorms

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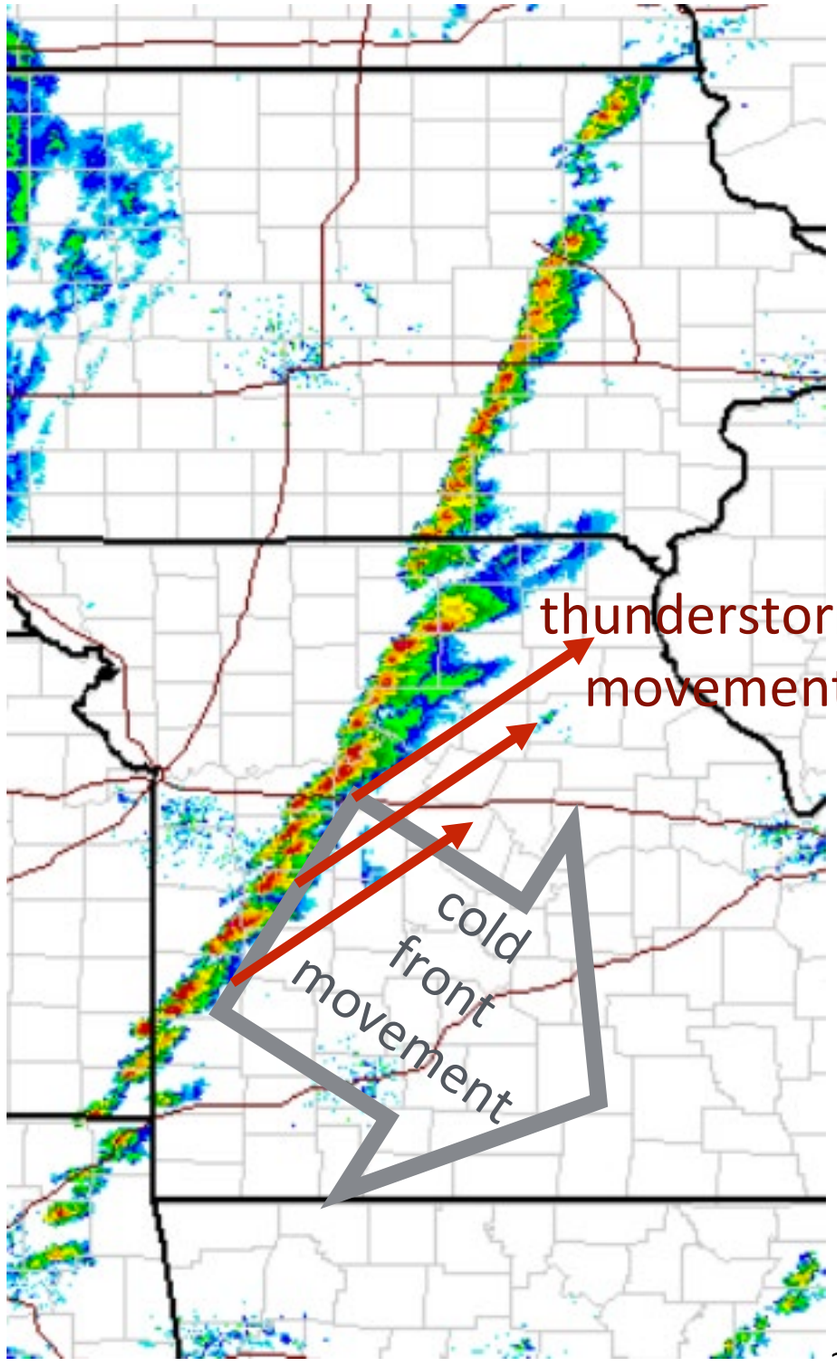
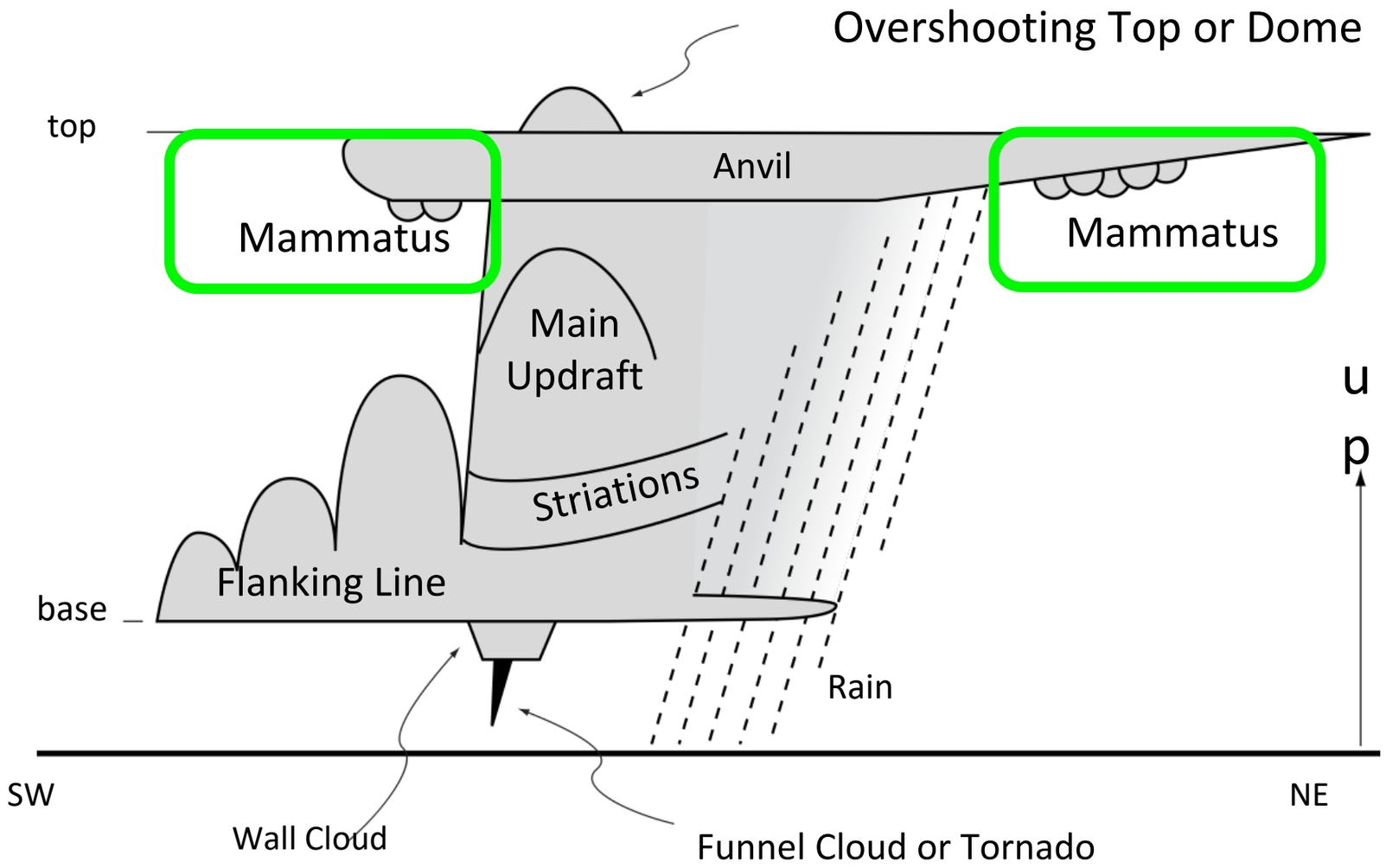
Video 2 - 07. Storm of Beauty (Pecos Hank, in class: only the **first 3:00 minutes**)

https://www.youtube.com/watch?v=0jkfnIBJRBQ



How to Recognize:
Mammatus Clouds

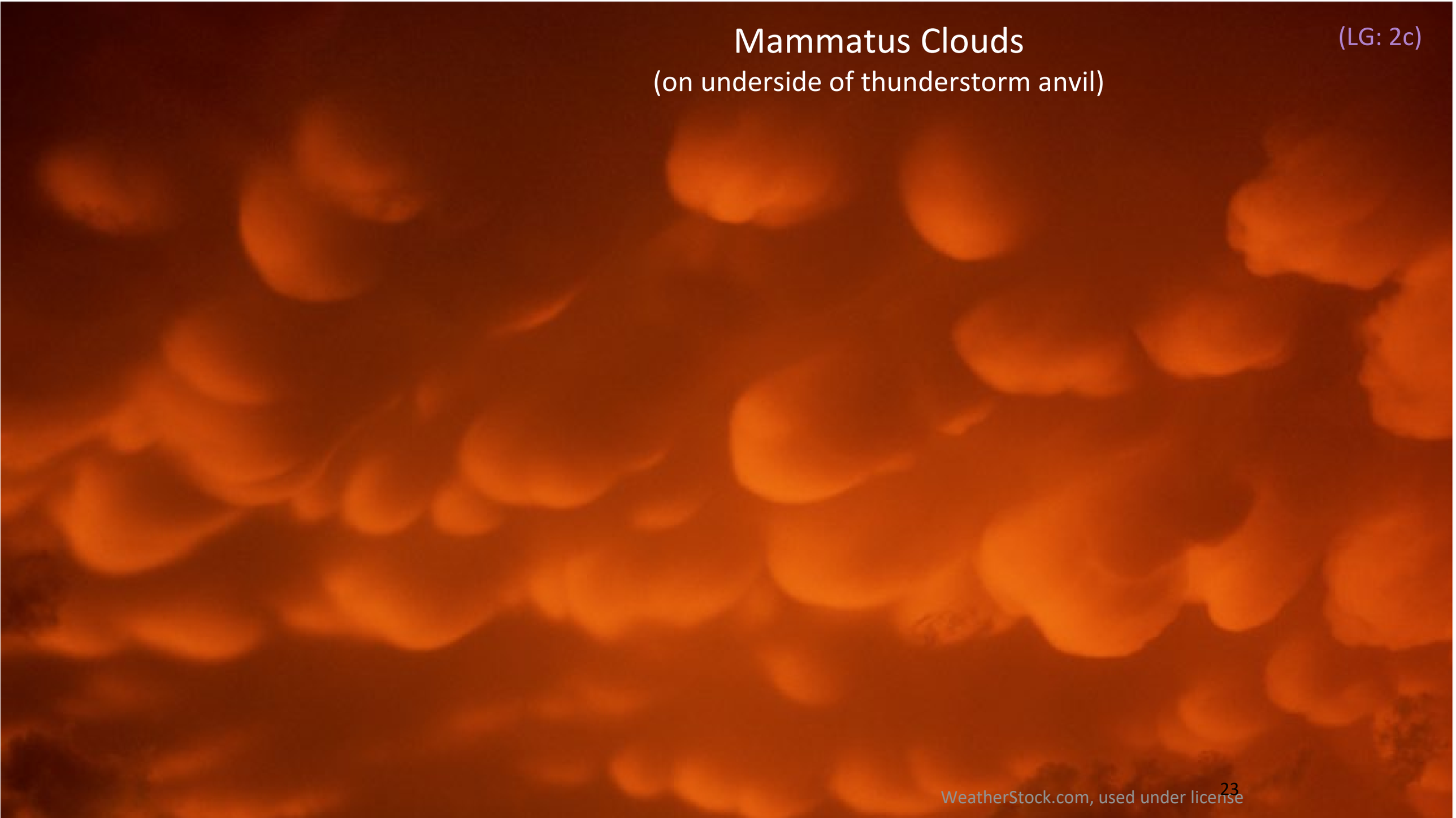
(LG: 2c)



Mammatus Clouds

(on underside of thunderstorm anvil)

(LG: 2c)



Supercell Videos from YouTube

Three types of **supercell**:

(1) **low precipitation** (LP) supercell. It can produce lots of hail.

(2) **classic** supercell, (with rainy downdraft & rain-free updraft)

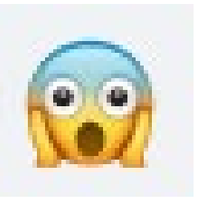
(3) **high precipitation** (HP) supercell, updraft mostly surrounded by rain.

Some are in-between or contain features of 2 or more types, and are called "hybrid" or "mixed mode" storms.

Watch on your own:

Day2-08 Overview of Supercells (Pecos Hank , 4:30)

https://www.youtube.com/watch?v=yvIKIgelY6g



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Some are in-between, and are called “hybrid” or mixed-mode storms.

Day2-YX LP in May 2021 (1:07)

Low-precipitation (LP) supercells are the most beautiful to photograph. LP supercells can produce the most hail. Here LP is near Cofferville, TX
https://www.youtube.com/watch?v=f3ciJHqY-1w

Day2-XZ LP in 2020 (2:39; skip first 20 s)

Low-precipitation (LP) supercells in Hershey, Nebraska, by F. McKinney.
https://www.youtube.com/watch?v=zzBylV2QkuI

Supercell Videos from YouTube

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Day2-25 Classic at Booker time lapse. 3 June 2013 (1:55, skip first 20 s)

https://www.youtube.com/watch?v=ak05BQ6eNLU

Other videos you can watch on your own (not testable):

Day2-20 Classic at Brisbane, Australia. Nov 2013 (2:30 play 2x speed)

https://www.youtube.com/watch?v=o1eP5WVM5bQ

Supercell Videos from YouTube

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Some are in-between, and are called “hybrid” or mixed-mode storms.

Day2-ZX Chasing an HP supercell in Iowa. 2015 (2:46, watch first 30 s)

https://www.youtube.com/watch?v=rfgU9yurI5c

Other videos you can watch on your own (not testable):

Day2-30 HP supercell in Lamar, CO timelapse. 2015

https://www.youtube.com/watch?v=L60AHze111o (0:20)

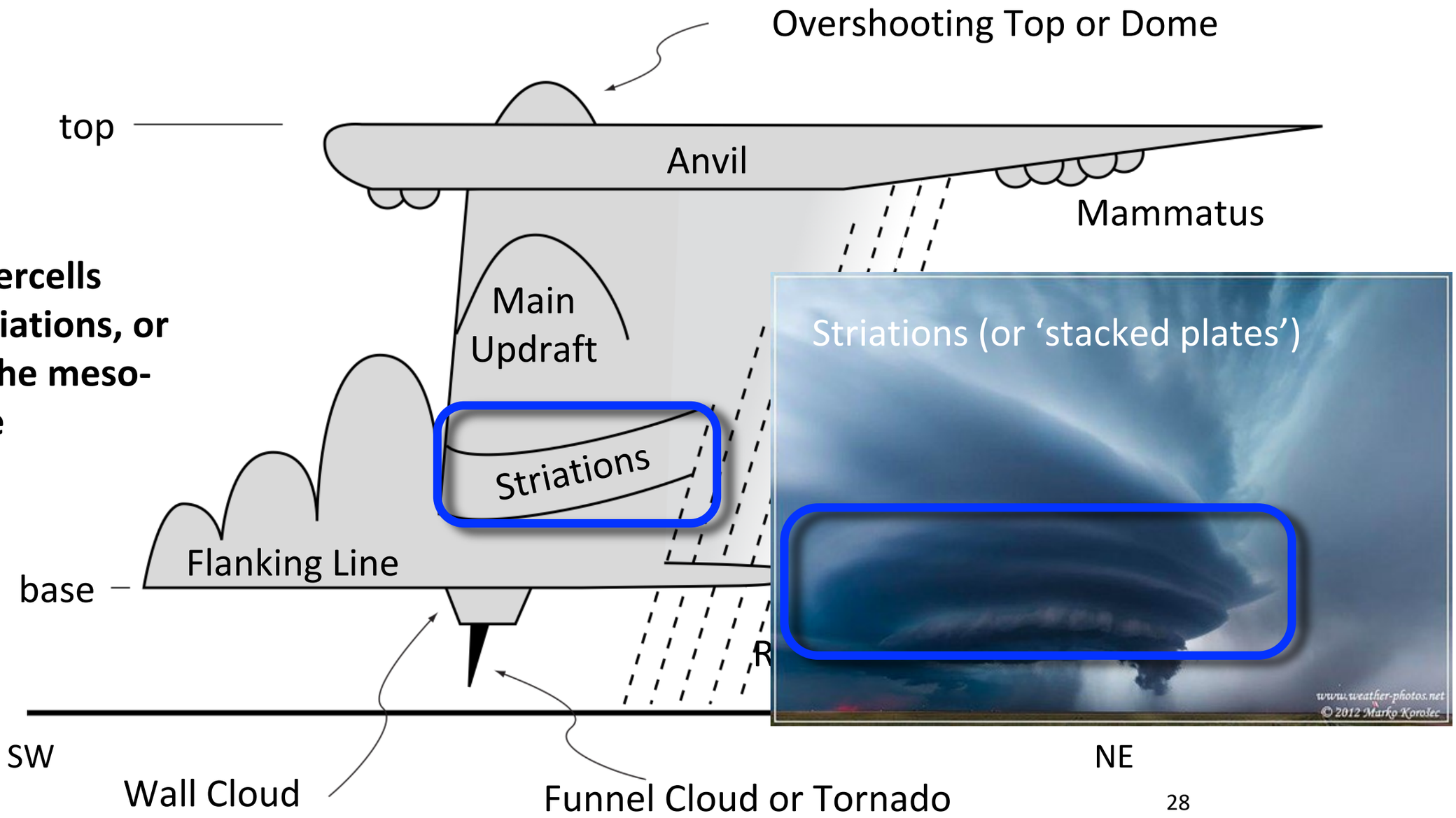
Day2-35 HP supercell in Texas. 2015

https://www.youtube.com/watch?v=trVMTXoDPGA (last 10 sec)

2. Recognizing supercells: striations

Learning Goals (LG): 2c

Rotating supercells typically have striations, or layers, around the meso-cyclone



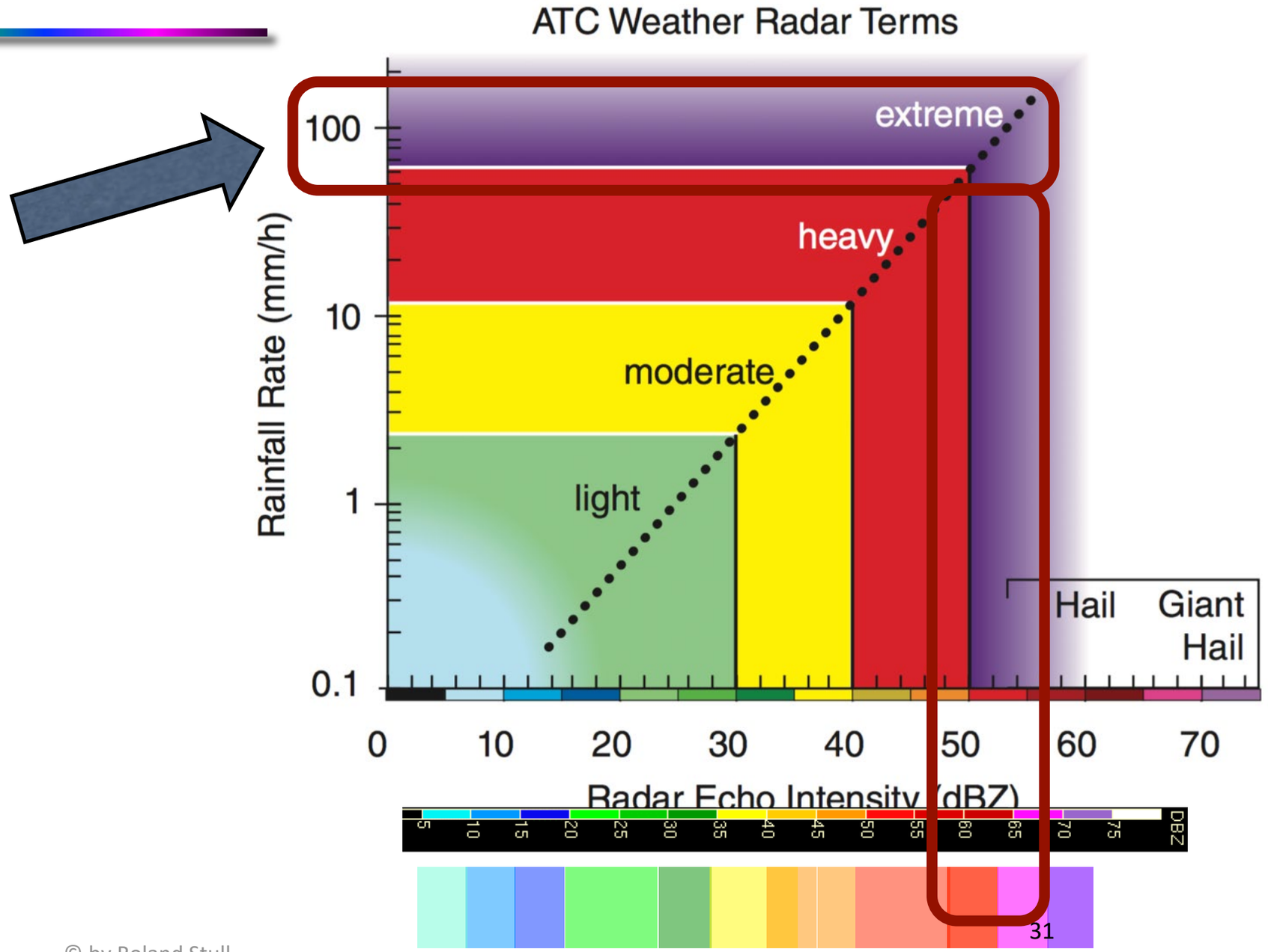
Road-map to Storm topics

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

Thunderstorms hazards: rain downpours

Extremely large rainfall rates (i.e., Downpours) can cause **Flash Floods**



Flash Flood Safety:
DON'T GO INTO FAST FLOWING WATER, **EVEN IN A CAR**

It takes just 30cm (12 inches) of flowing water to carry off a small car.
More than half of the deaths from flooding each year in the US happen in vehicles.

Day 2 Video 44:

NWS Flash Floods - Turn Around (0:30)

https://www.youtube.com/watch?v=5JUsYrjg6xU

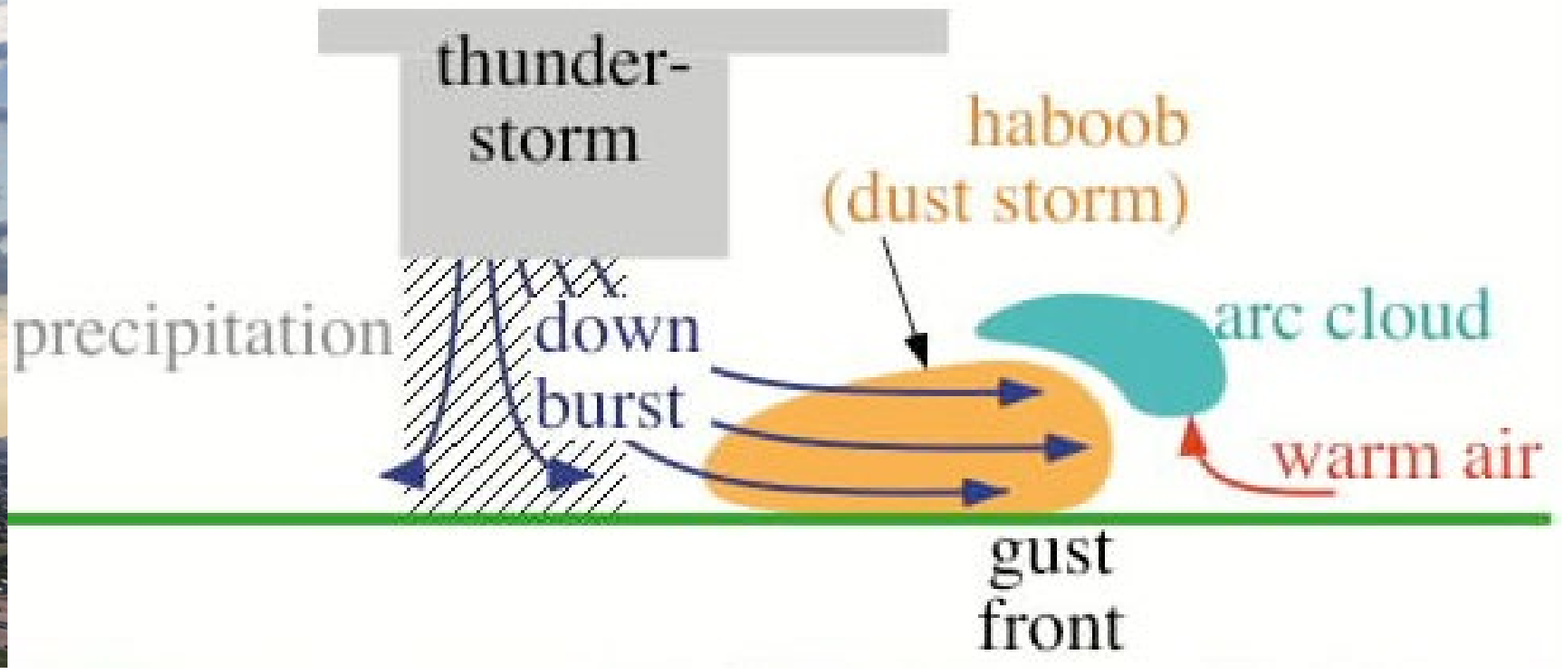
Watch on your own:

Day 2 Video 45:

NWS Animation of flash floods vs cars (1:00)

https://www.youtube.com/watch?v=eI6mIlHKrVY

Downbursts & Gust Fronts (of air)



- Downdraft speeds of 20 to 90 km/h.
- Horizontal wind speeds near ground of up to 250 km/h.
- Microbursts are small diameter (≈ 1 km) downbursts.

Hazards: Downbursts & Gust Fronts

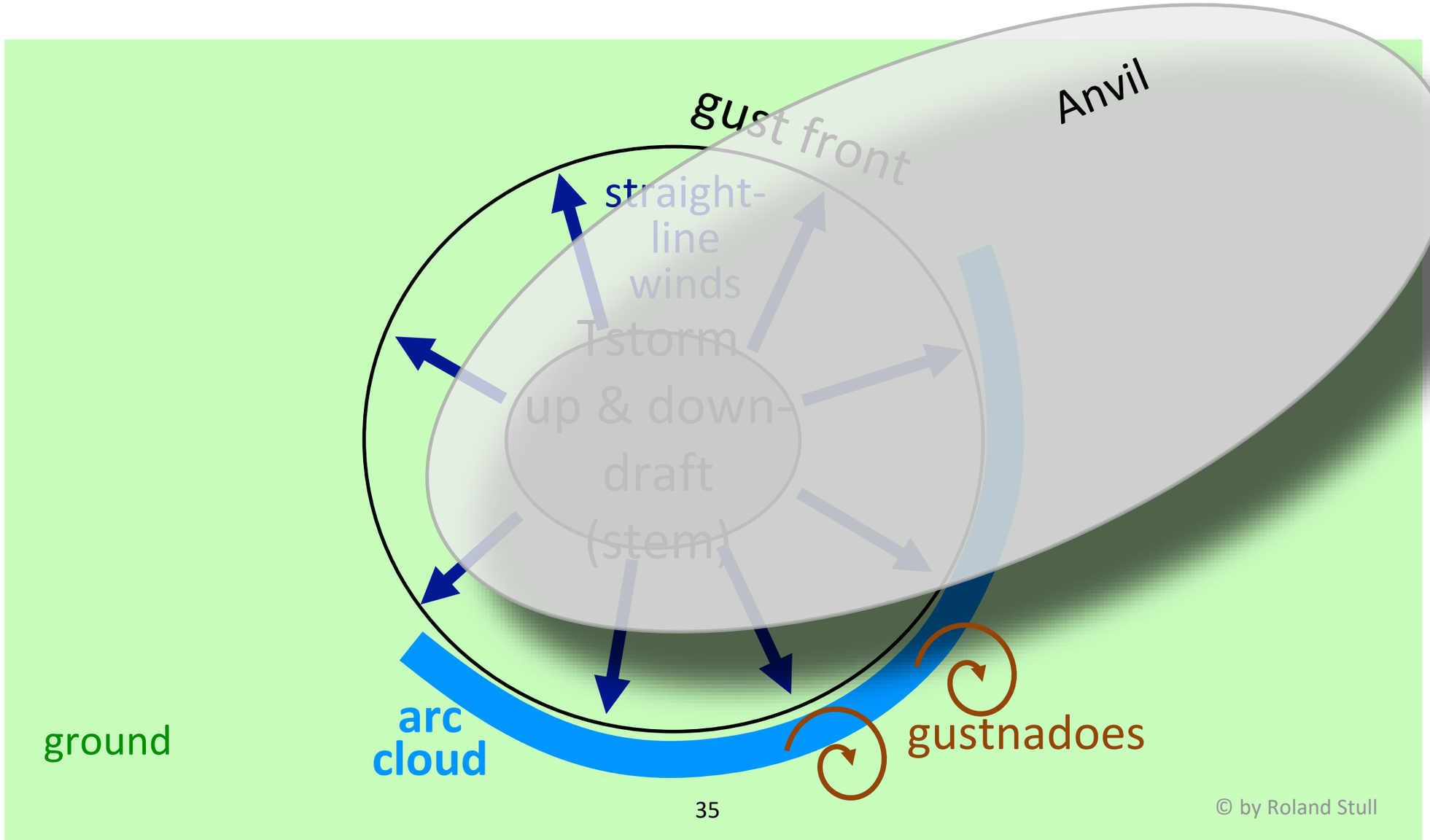
- What: Downburst - cold (dense) air sinking.
- Why: Tstorm can create dense air where **rain** falls; due to **evaporative cooling** of 'virga': precipitation that evaporates before it reaches the ground
- Risks: Often invisible, but a hazard to aircraft.

- What: Gust front - leading edge of cold, horizontal straight-line winds.
- Why: downburst air hits ground & spreads outward in straight lines.
- Visible: haboob (if dry ground); arc cloud (if moist air); gustnado
- Risks: can blow down large trees and destroy weak structures (mobile homes; out-buildings); hazard to aircraft during take-off/landing.

- Safety: avoid weak bldgs & trees that could fall.
  Airports have sensors; flights avoid; pilots trained.

Downbursts & Gust Fronts (of air)

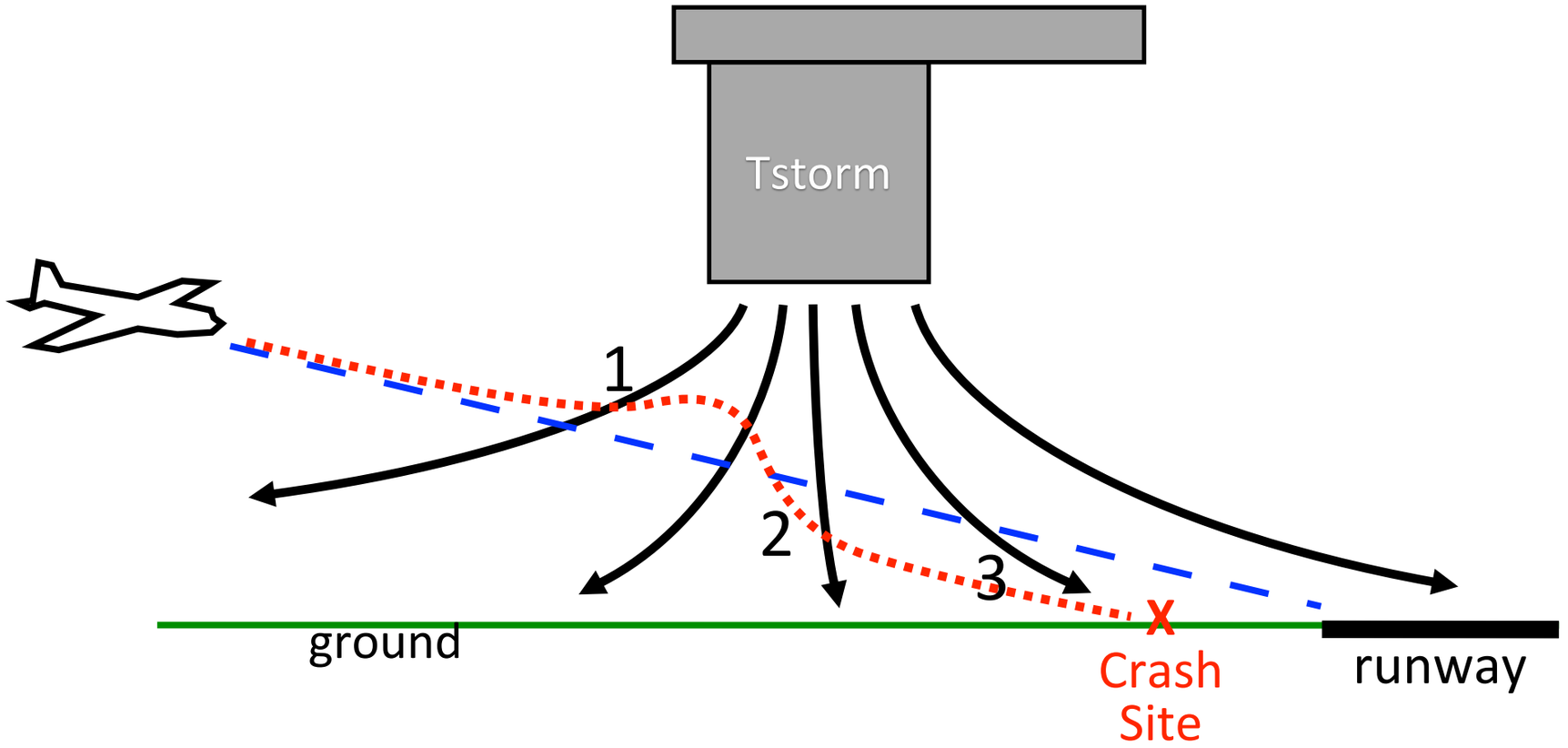
Top view:



Downbursts & Gust Fronts (of air)

Crash of Eastern Airline Flight 66.

Killed 112 people at JFK airport in NY, 1975.



LG 2c, d

WeatherStock - used under license

WeatherStock - used under license

Arc Clouds along Gust Fronts

Downbursts & Gust Fronts

Day 2-60 Shelf cloud 2010 at beach in MI (3:27 , play 5x speed)

https://www.youtube.com/watch?v=mOVwlfrKN2g

Watch on your own (Not testable).

Day2-50 Gust front 2013 Brisbane, AU (1:13)

https://www.youtube.com/watch?v=qwKIq1fKSM8

Day 2-55 Gust front 2014 Dover, UK (1:13)

https://www.youtube.com/watch?v=jJB05Hcjch8

Downbursts don’t only happen in thunderstorms…

cloud

Virga (= precipitation that evaporates before the ground)

LG 2c, d

Another Hazard of down-bursts:

Haboobs
(sand storms)

NWS, Phoenix

D.Newton, wunderground.com

Haboobs / Dust Storms

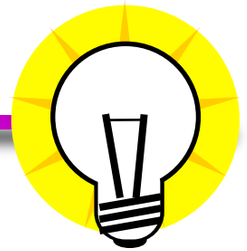
Video Clips

Day 2 - Video 48 Haboob segment (view only 6:15 - 7:40)
Monsoon V video by Mike Olbinski
https://www.youtube.com/watch?v=TC75USRhdho

Watch on your own (Not testable):

- Day 2-65 Dust storm in Iraq (2:33, play 5x)
  https://www.youtube.com/watch?v=iC2qlU8G8vw
- Day 2-75 News Report of 2011 storm AZ (4:45, view first 1.5 minutes)
  https://www.youtube.com/watch?v=RD5I9UhbRgg
- Day 2-70 Driving into dust storm in AZ (9:56)
  https://www.youtube.com/watch?v=3glyRZLZAR0
- Day 2-80 Gustnadoes and Haboob (Pecos Hank)
  https://www.youtube.com/watch?v=vVlwbqglCDs

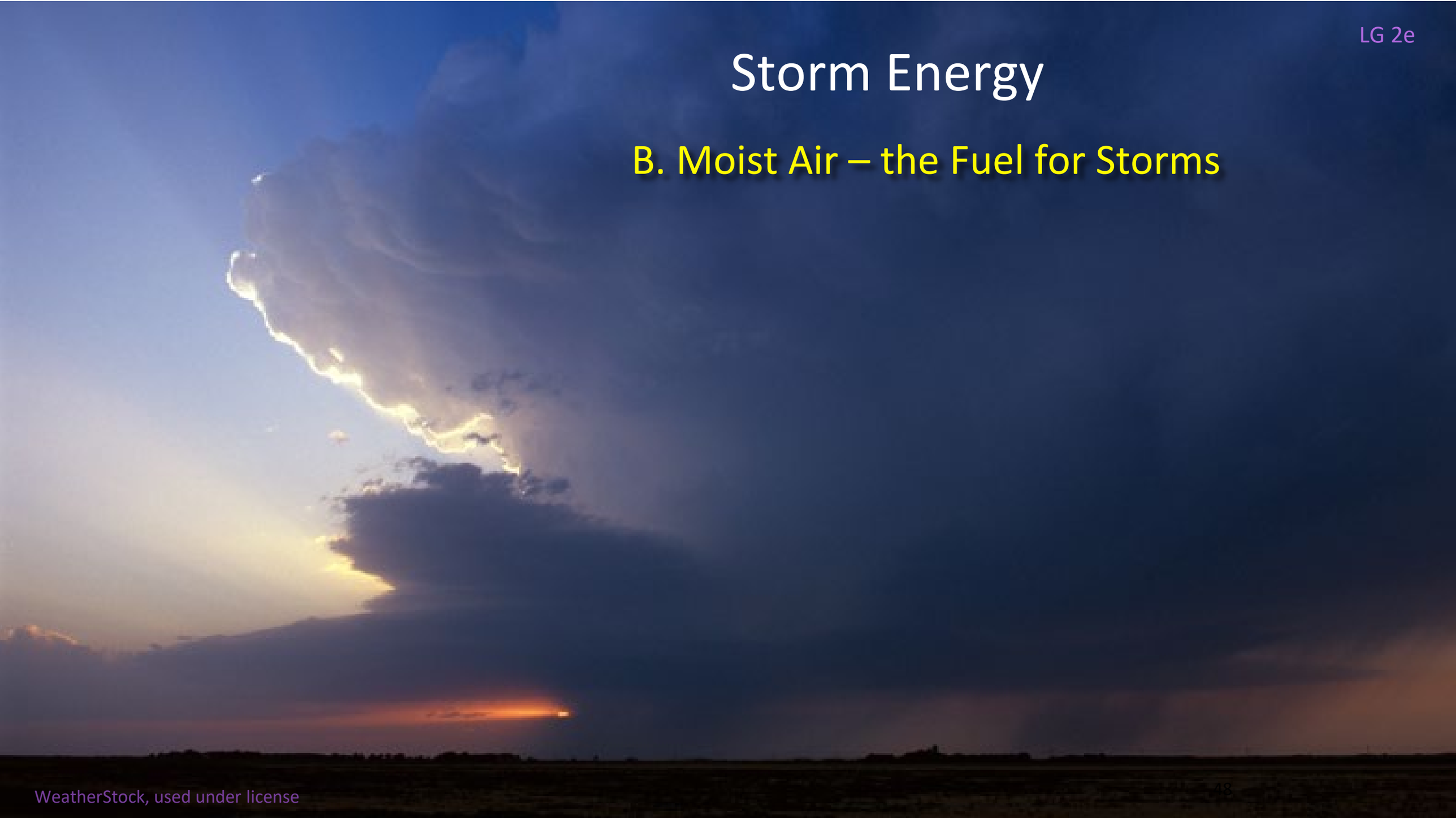
Insights



- Instead of memorizing the end effects, if you understand the underlying causes & processes, then you can make predictions for new situations.

Storm Energy

B. Moist Air – the Fuel for Storms



Storm Organization

Storms have special organization and capability to:

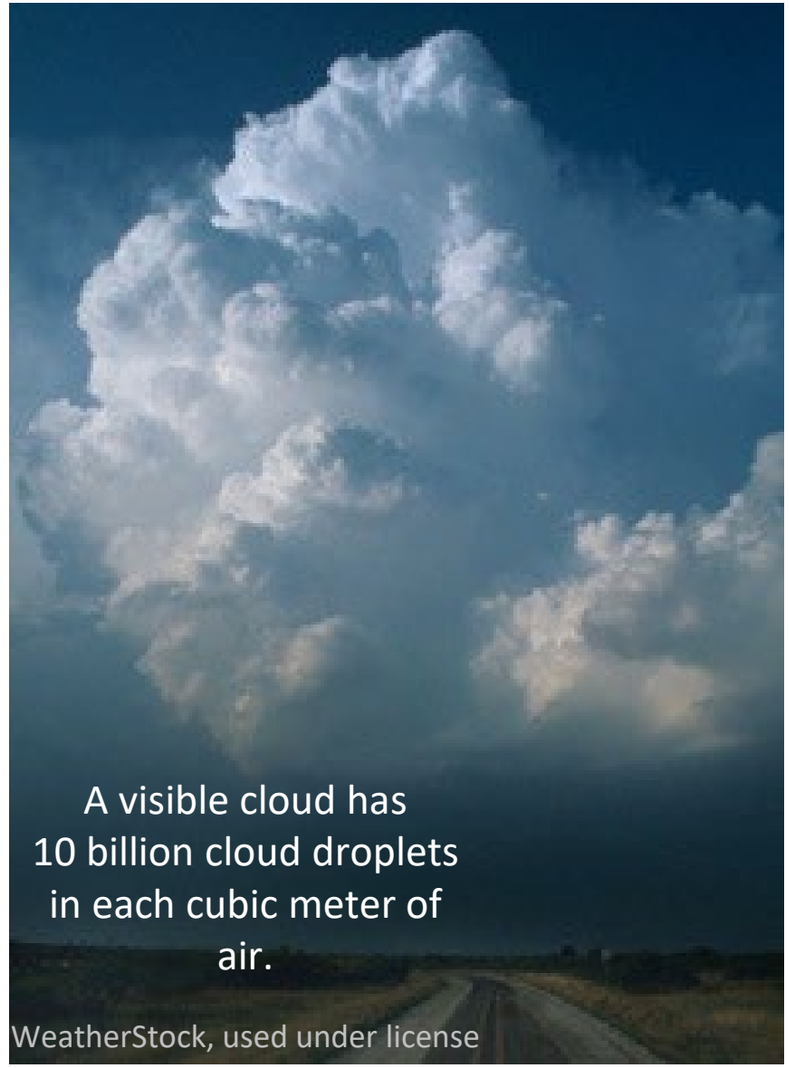
- draw in humid air,
- condense the moisture in this air
- release its heat into the storm, increasing the strength of the storm

This results in precipitation & violent winds

Thus, we need to look at concepts of:

1. humidity
2. saturation
3. latent heat

Plus advection and adiabatic cooling



1. Humidity

Air = mixture of gases:

0-4% water vapour +
78% (±3%) of nitrogen +
21% (±1%) of oxygen +
Trace gases +
Liquid water droplets

Humidity is the **amount** of **water vapour** in the air.

There are many humidity variables (i.e., many ways to **quantify** humidity.)

A Humidity Variable: Mixing Ratio (r)

Mixing ratio =
the amount of water vapour
divided by
the amount of all other gases

Examples.

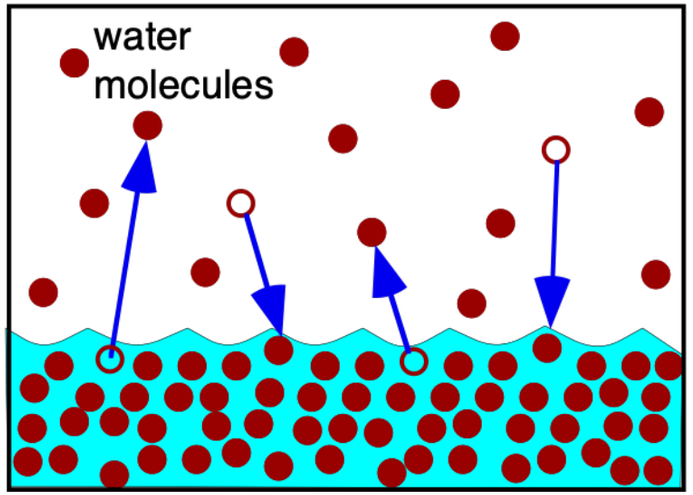
(1) If you mix 2 parts water vapour and 5 parts all other gases.

Then mixing ratio is $r = 2/5 = 0.4$

(2) If you mix 78 parts of N_2 + 21 parts of O_2 + 1 part of H_2O,

Then mixing ratio is $r = 1 / (78+21) = 1/99 = 0.011$ ← typical value

2. Saturation – an Equilibrium between Evaporation & Condensation



- Water vapour is special -> can easily **condense** into liquid.
- Constant exchange of H_2O molecules occurs between vapour & liquid:
  - (vapour to liquid) = **condensation**
  - (liquid to vapour) = **evaporation**

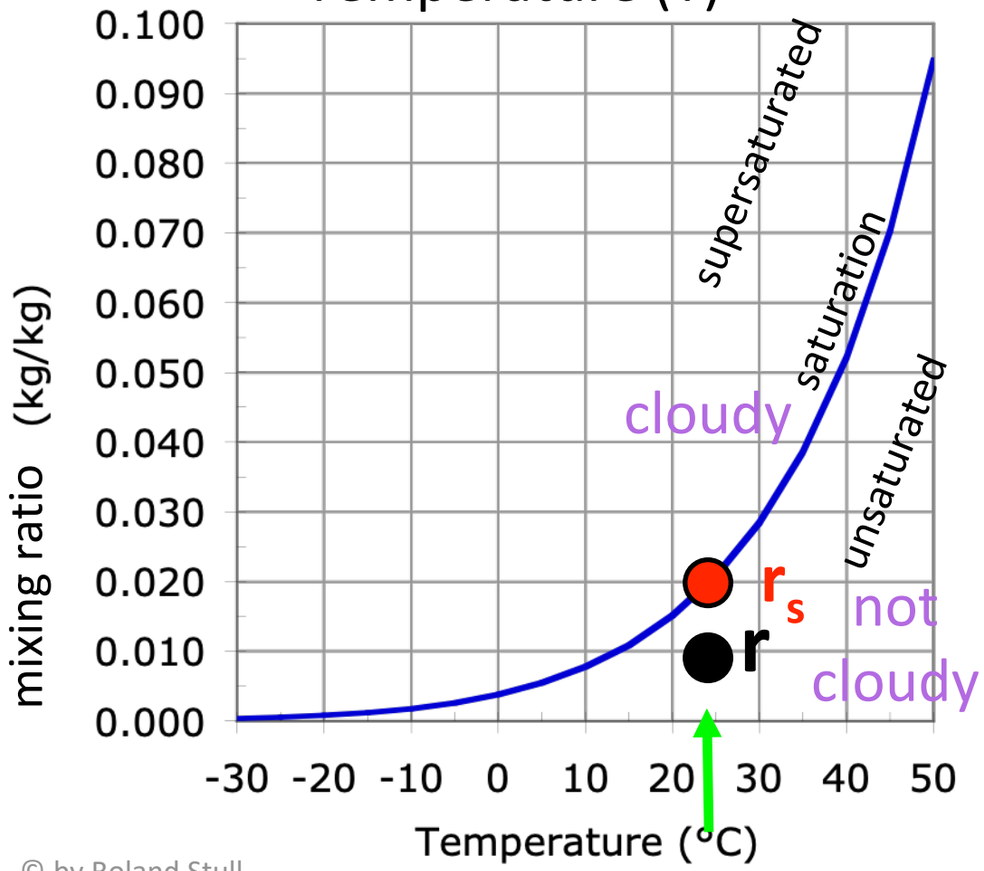
- The mixing ratio tends to approach an equilibrium where condensation matches evaporation. This equilibrium is called **saturation**.
- For all practical purposes, **saturation value** is the **maximum humidity** air can hold.

2. Saturation – an Equilibrium between Evaporation & Condensation

Saturation value is important in controlling atmospheric humidity.

- **Warmer air can hold more water vapour at equilibrium than colder air!!**
- Air that contains the maximum amount of water vapour = saturated (i.e., cloudy or foggy)
- Air holding less = unsaturated (i.e., not cloudy)

Saturation Mixing Ratio (r_s) increases exponentially with Temperature (T)



Advection & Adiabatic Cooling

Advection = movement of air by the wind.
Water vapour can be advected into a thunderstorm by the wind.

- When a thermal of unsaturated air rises **adiabatically** (with no heat transfer to the surrounding environment), the air cools roughly **10°C/km of rise** (because of pressure differences)

- Cooler air can hold less water as vapour

- Therefore, some vapour must condense into liquid droplets.

- But condensation releases latent heat, providing energy for the storm….

3. Storms strengthen when latent heat –> sensible heat.

If the Saturation Humidity value becomes smaller than the actual Humidity, then condensation occurs.

This condensation does 3 things:

1. releases the stored **latent heat** back into sensible heat to make storms warmer – this can make the storms even stronger
2. **reduces the humidity** down to the equilibrium (saturation) value
3. produces or increases **liquid cloud drops**, which can grow to become **rain drops.**

The release of latent heat increases the strength of the storm

Instructor: Doug McCollor

Summary of Day 2

- **More Thunderstorm Fundamentals**
  4. Squall-line & Supercell thunderstorms & mesocyclones
  5. Observing Thunderstorms, with satellite & radar

- **Hazards: Downpours (flooding), Downbursts & Gust Fronts**

- **Storm Energy: Moist air – the fuel for storms**

Next Class: Tornadoes