EOSC 114 - Storms

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)

Prof. Roland Stull

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

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

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

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

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

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

Observing and Monitoring using Remote Sensors

LG 2c

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

Satellite

scijinks.nasa.gov

Radar

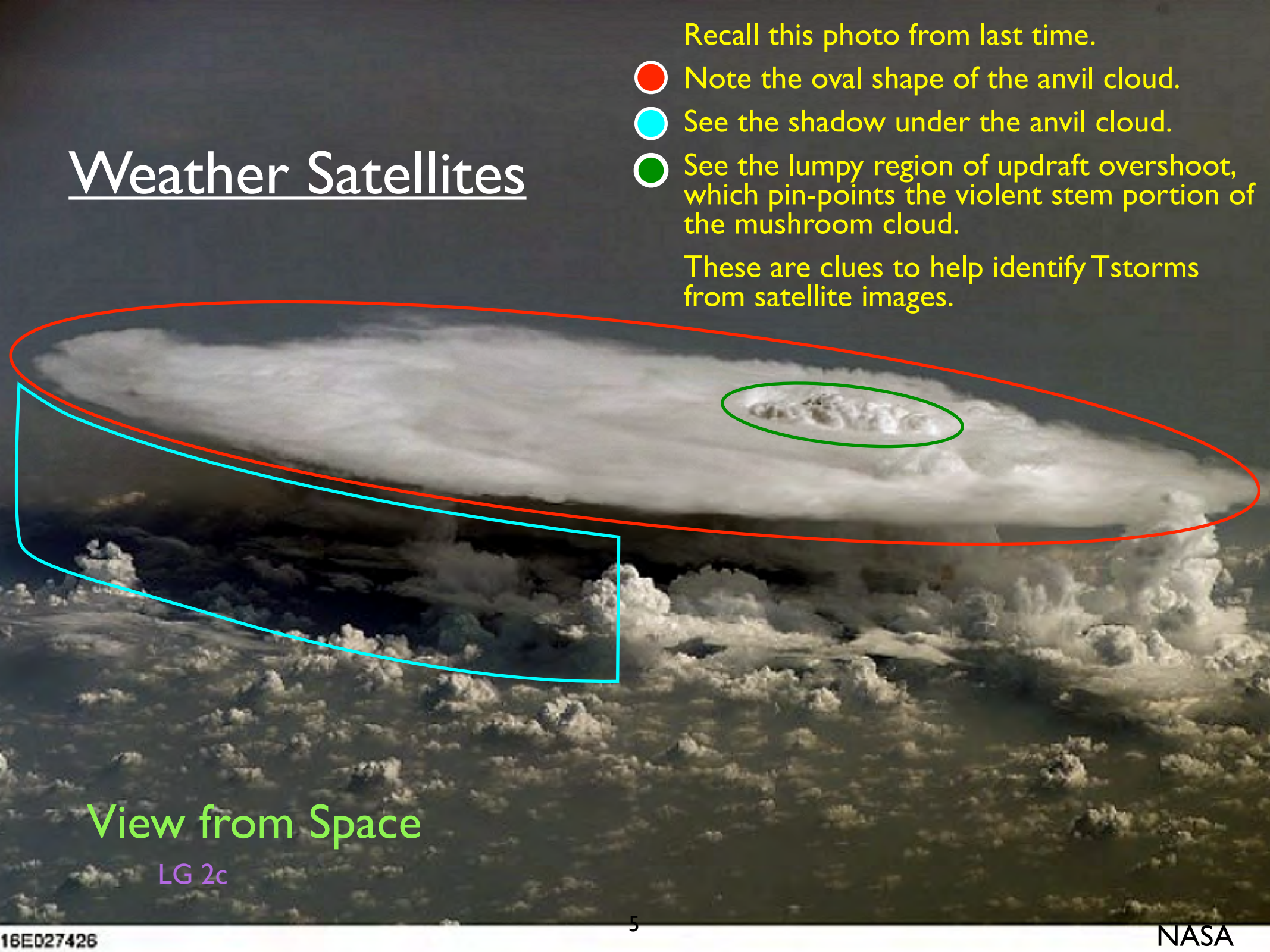
USGS

Weather Satellites

Recall this photo from last time.

- 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

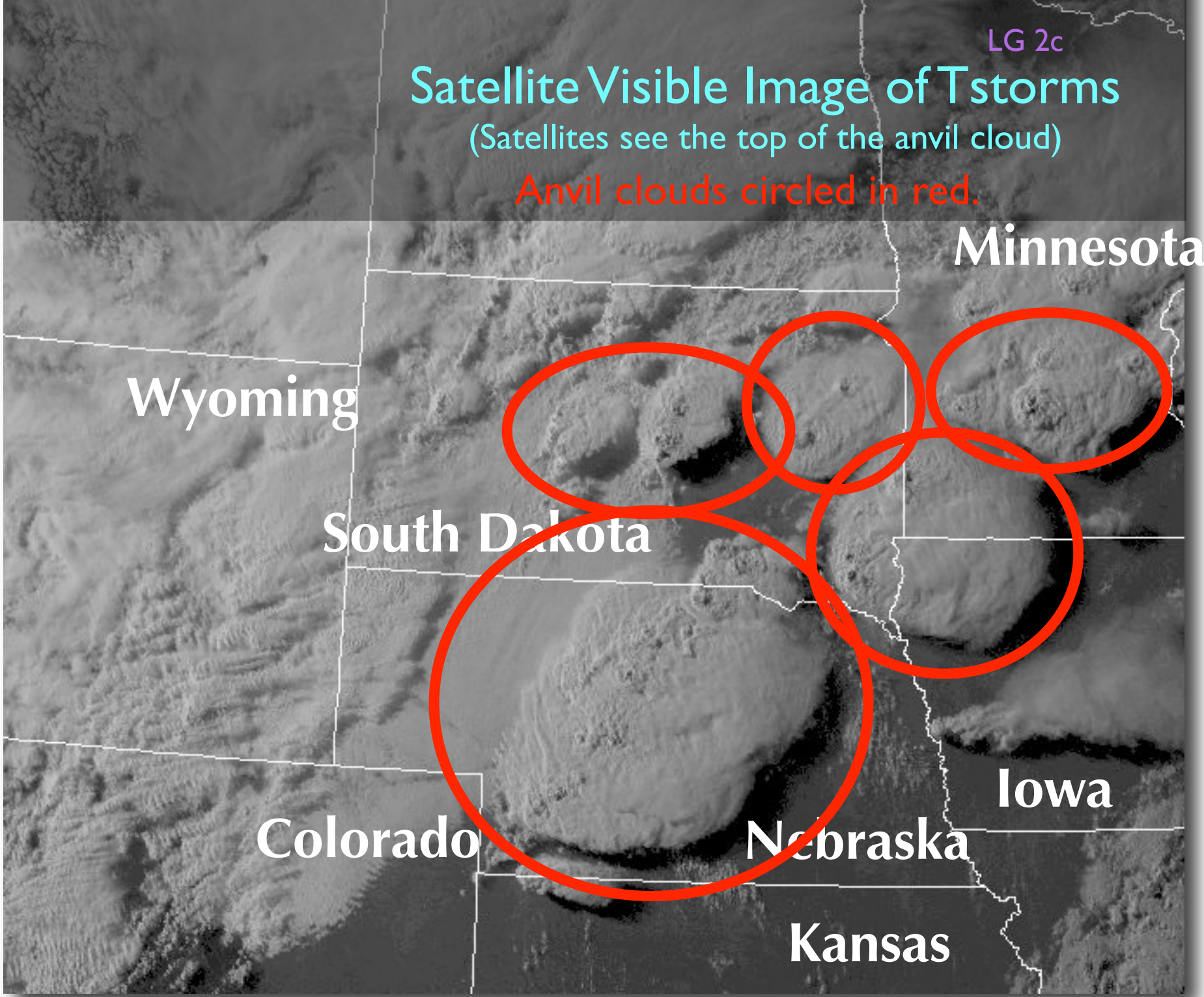
LG 2c

LG 2c

Satellite Visible Image of Tstorms

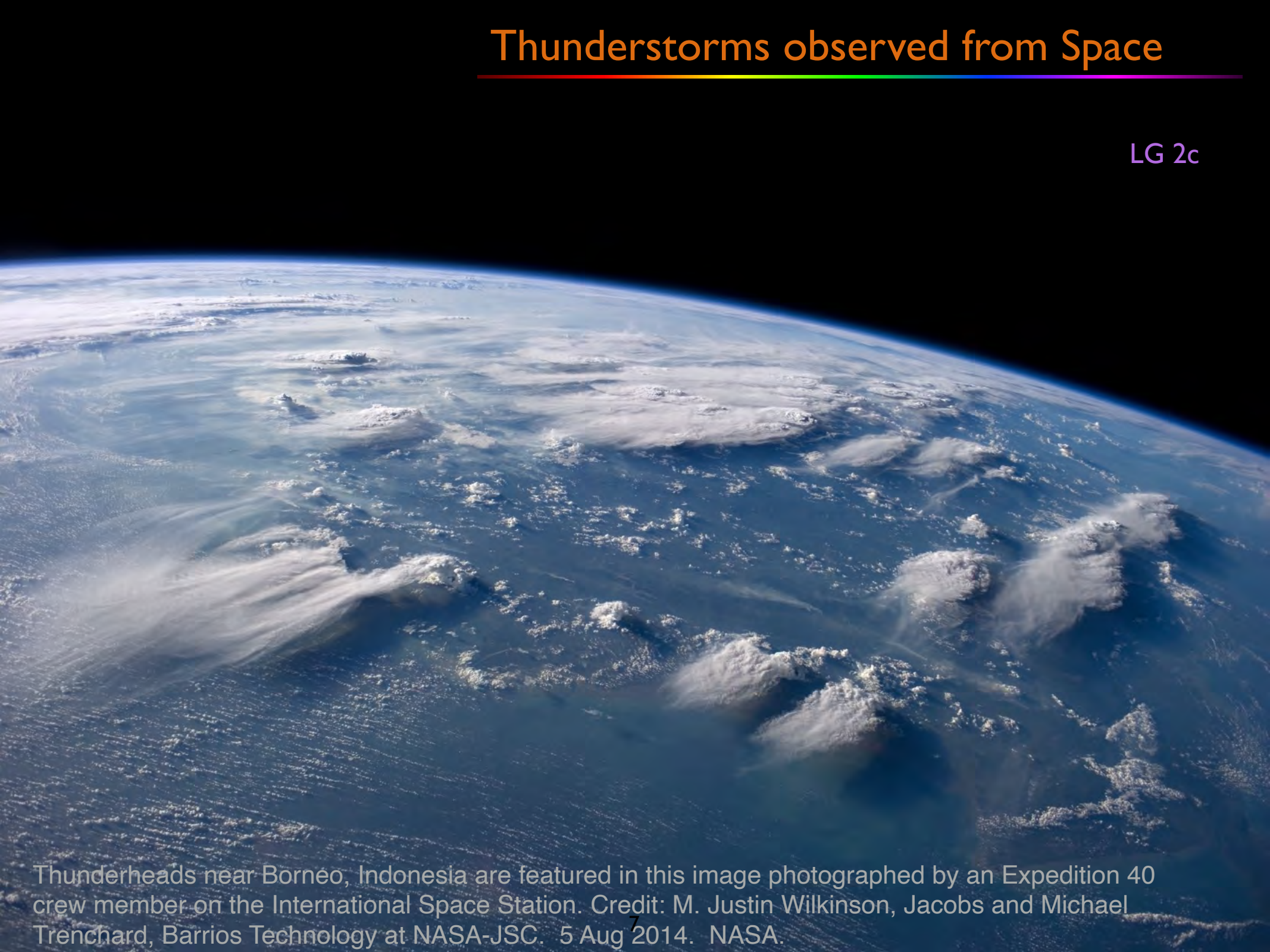
(Satellites see the top of the anvil cloud)

Anvil clouds circled in red.



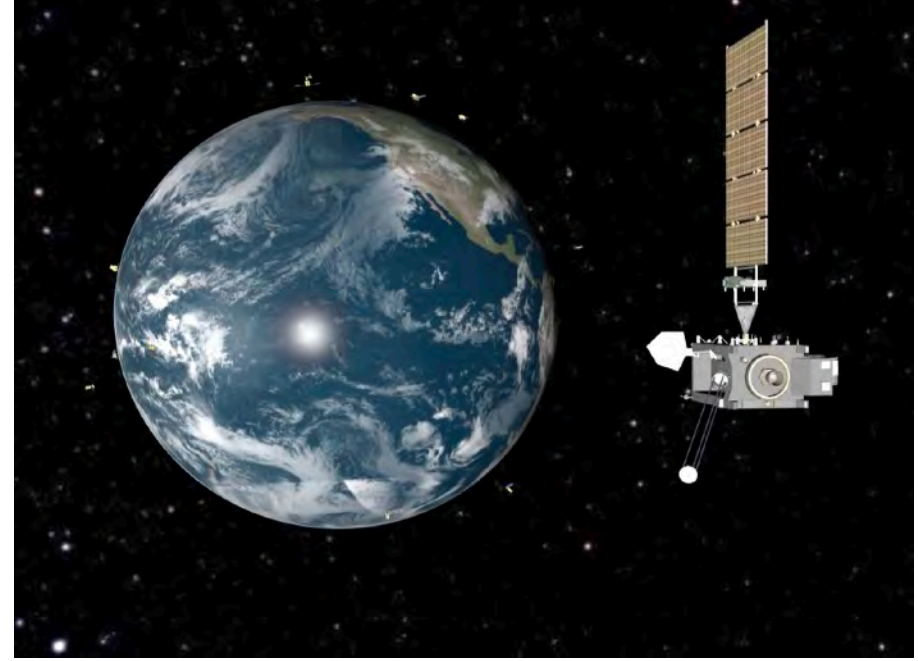
Thunderstorms observed from Space

LG 2c



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 Trenchard, Barrios Technology at NASA-JSC. 5 Aug 2014. NASA.

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



Day 2 Video 32:

Satellite visible time-lapse of a 2017 Thunderstorm evolution (1:00):

http://rammb.cira.colostate.edu/dev/lindsey/loops/24may14_g14_vis_texas_loop.mp4

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

Day 2 Video 33 (view in web browser):

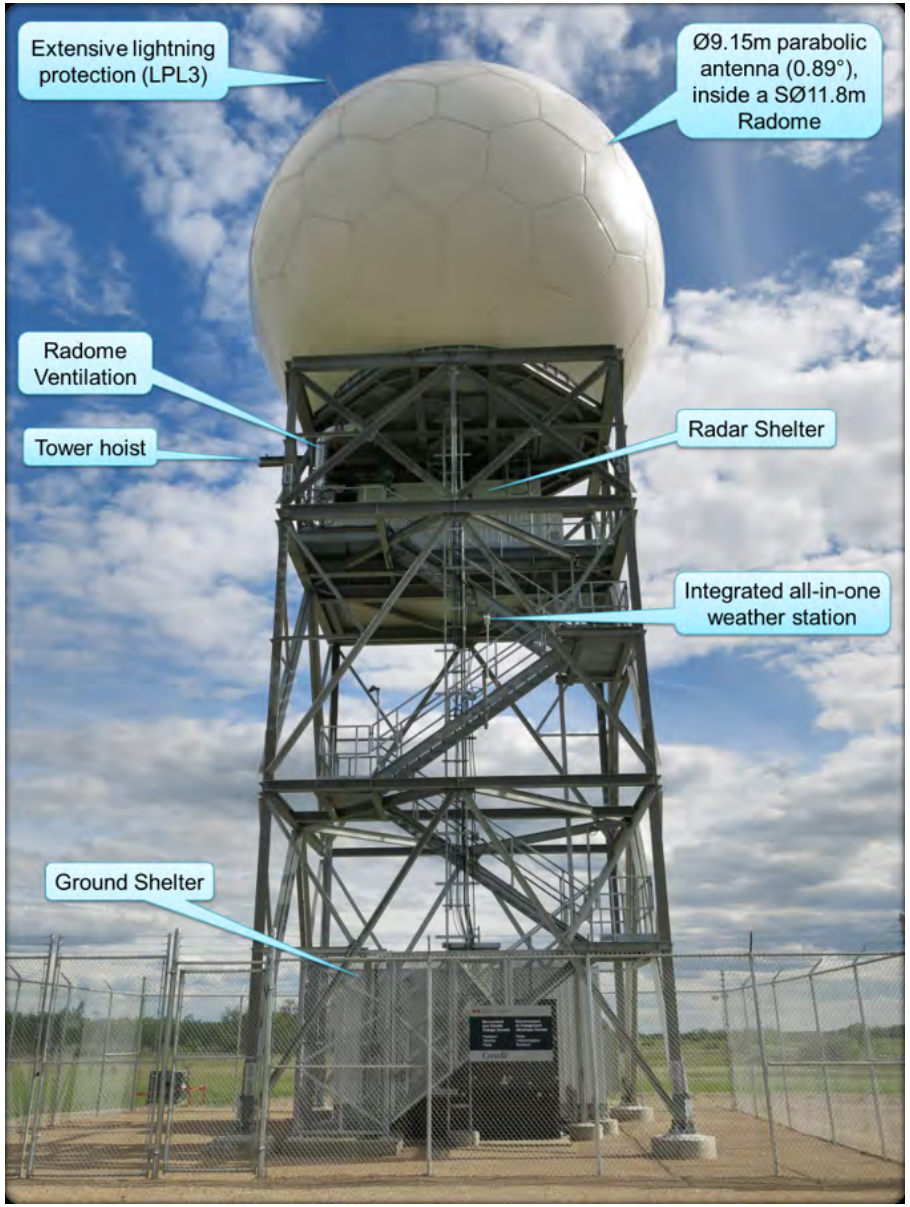
Satellite visible & IR time-lapse of (2019) Hurricane Dorian evolution (1:00):

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

LG 2a,c



ECCC

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.

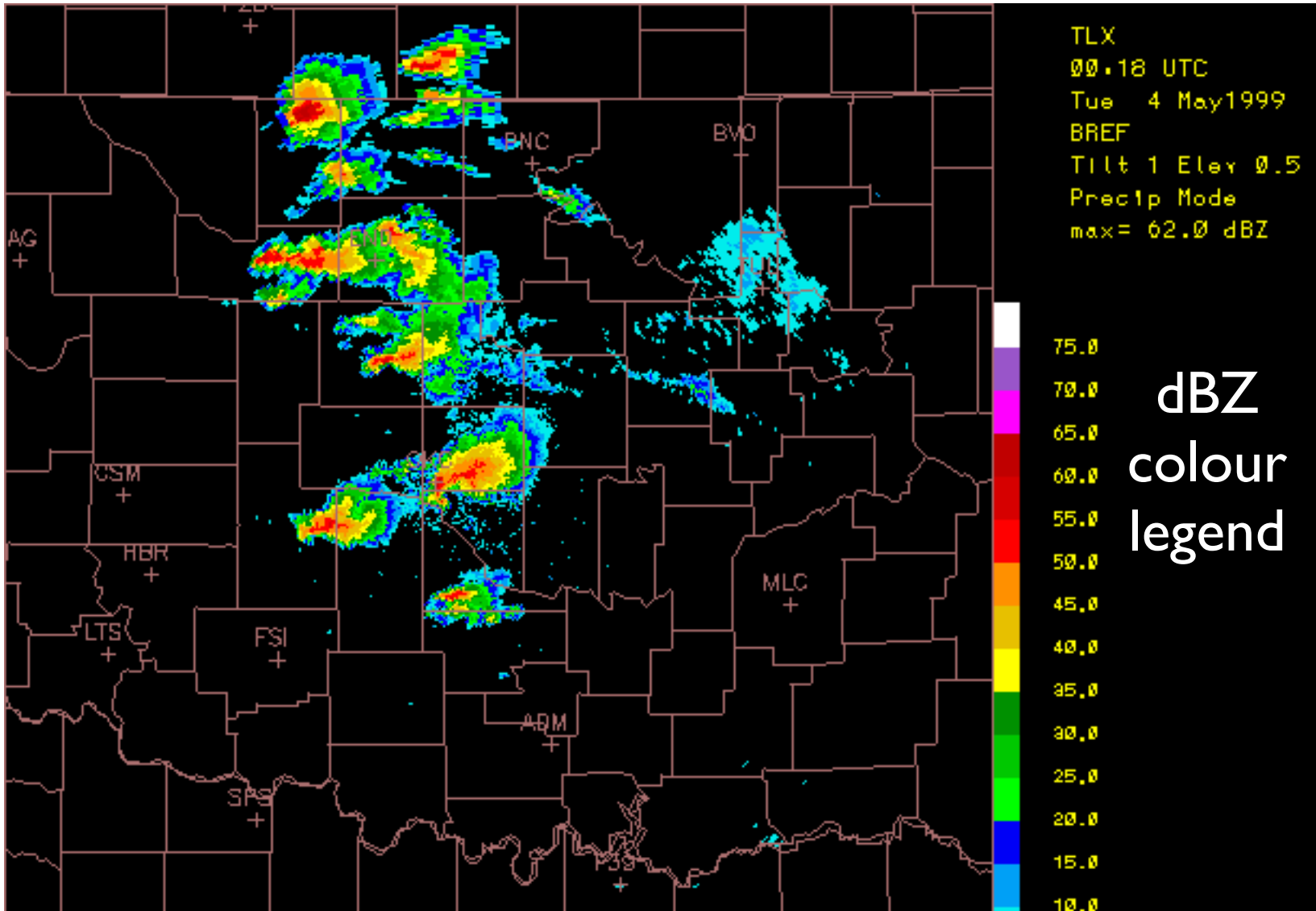
Another radar will be put on the west coast of Vancouver Island.

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)

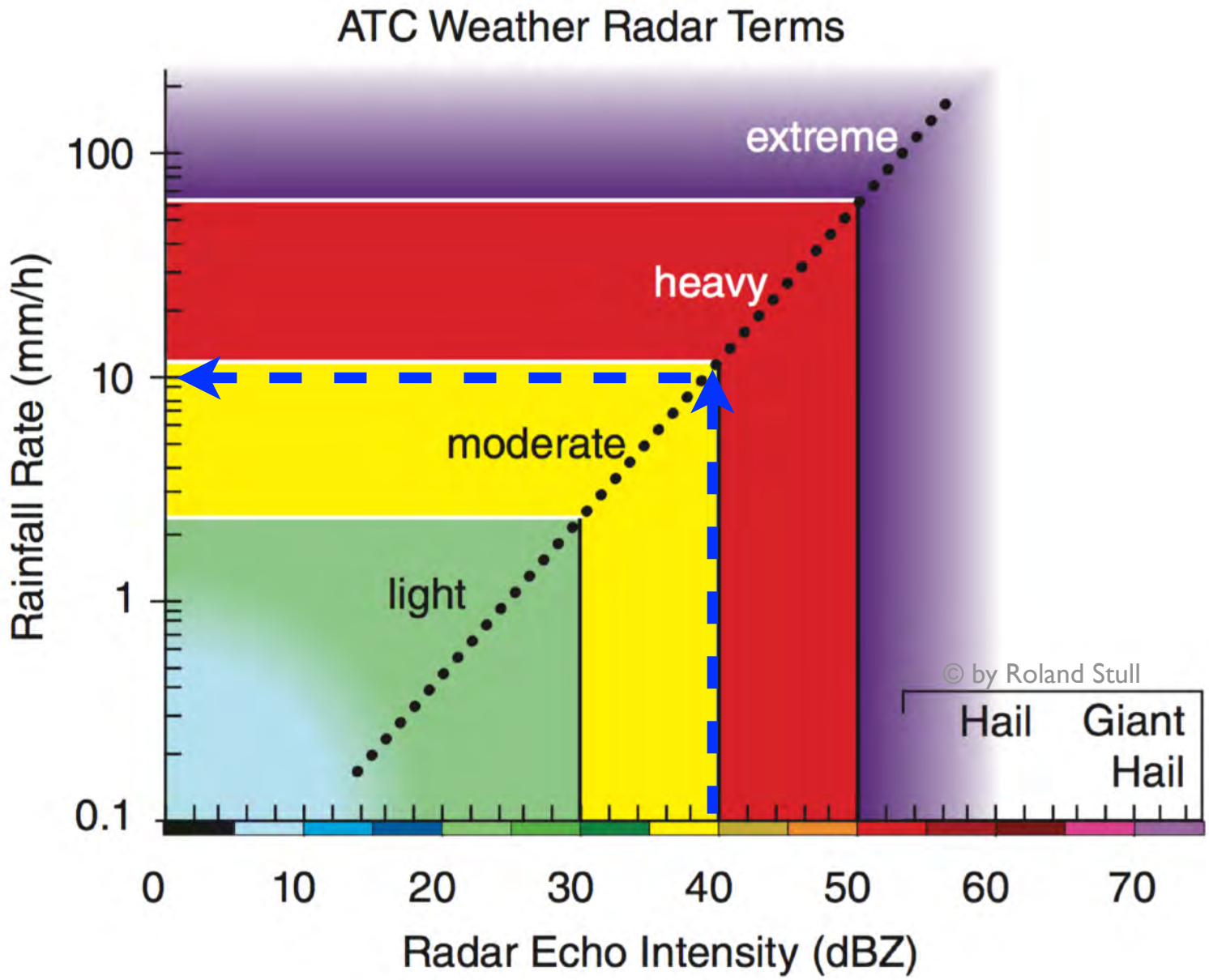


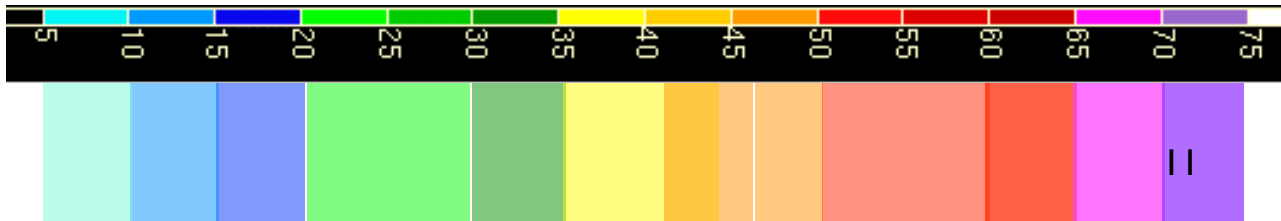
from NWS

dBZ:
A Disaster Intensity Scale for

Radar-echo Strength

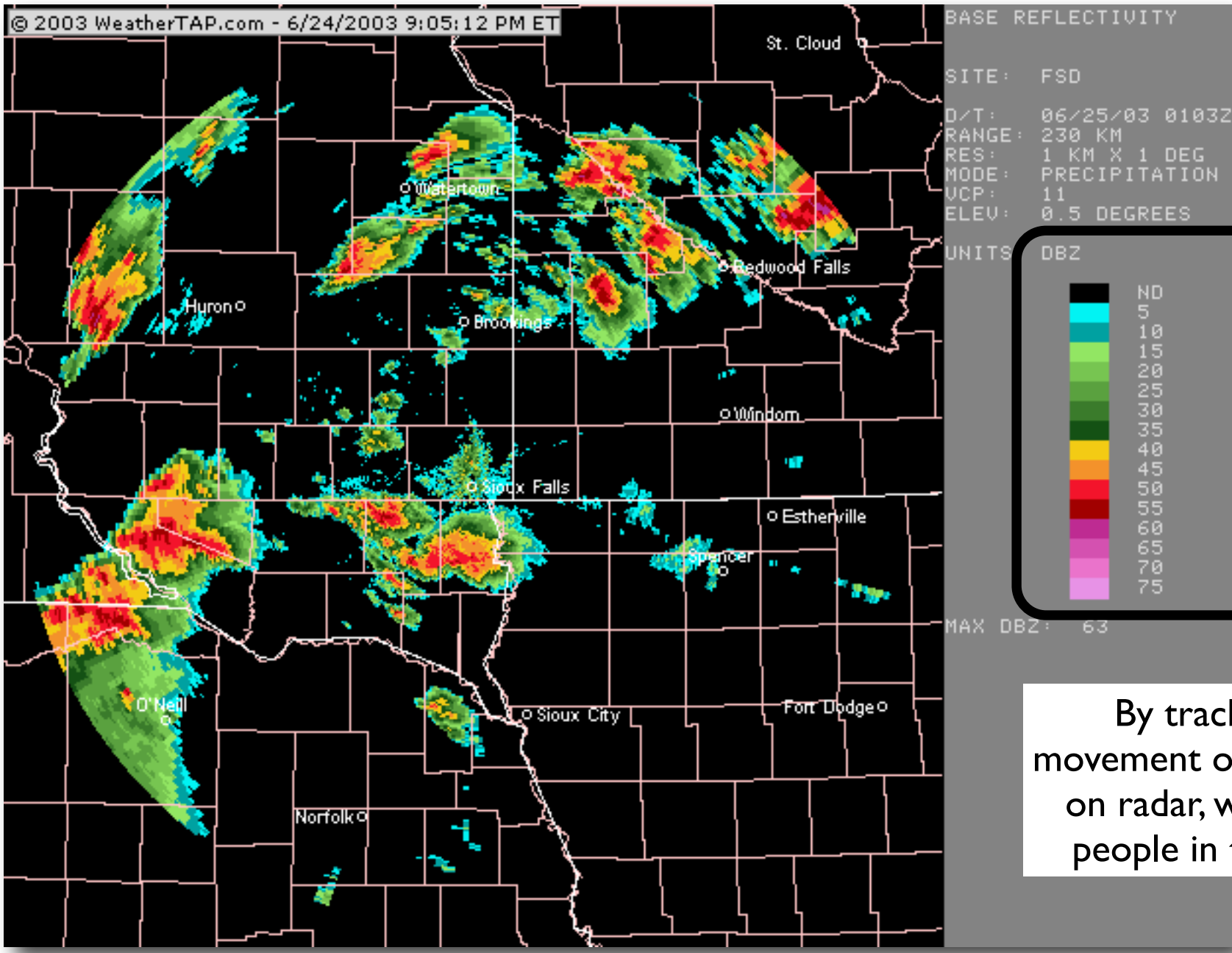
(an indicator of Rainfall-Rate)





dBZ = radar echo intensity (in decibals).

Radar Loop (video) of Thunderstorms



LG 2a,c

dBZ

By tracking past movement of Tstorm cells on radar, we can warn people in their paths.

Weather Radar Damaged by winds in Hurricane Irma 2017

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

Thunderstorm Cells : Squall lines & Supercells

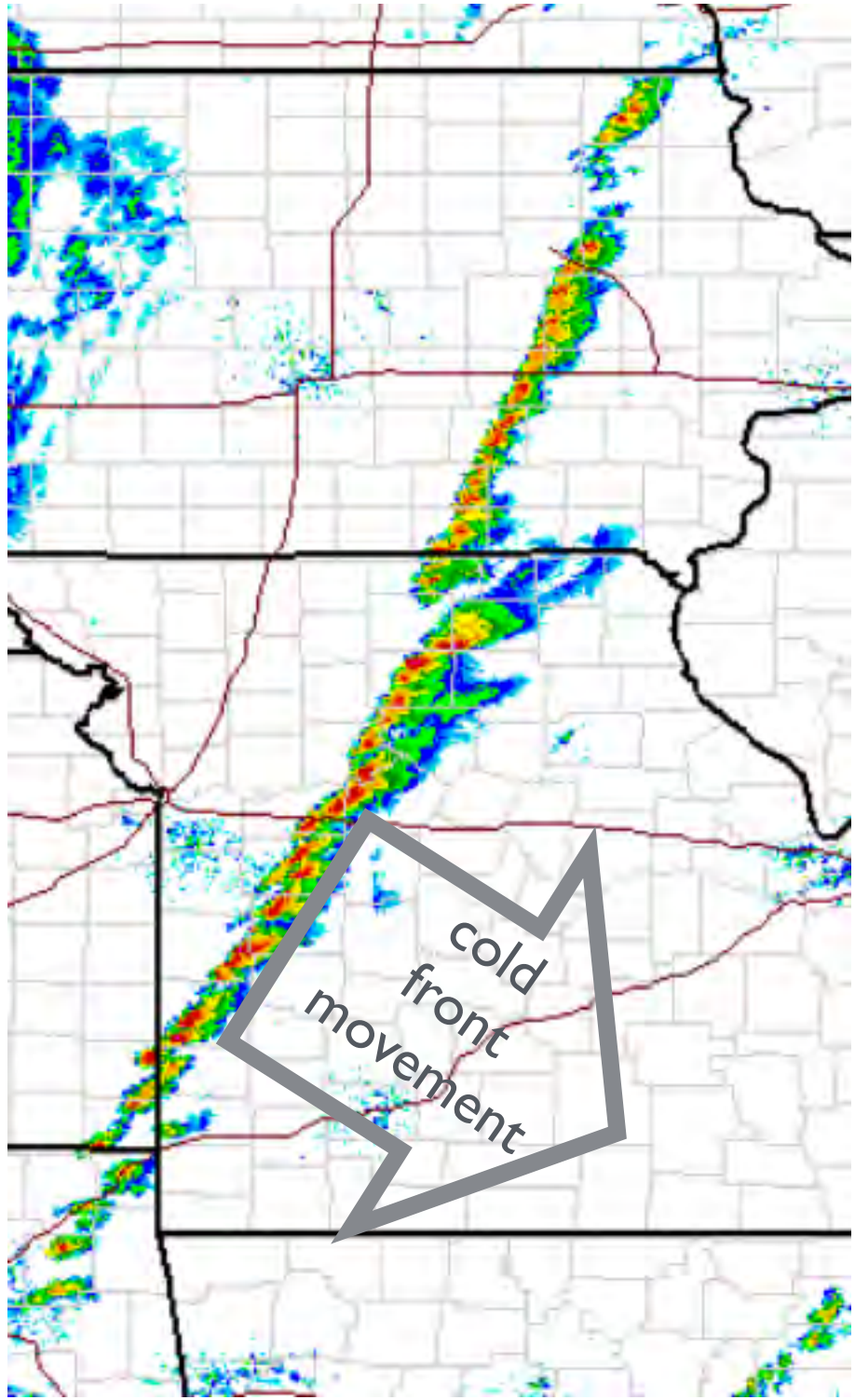
- cumulonimbus (thunderstorms) are made of large cells that evolve during 15-30 min.
- most thunderstorms (thunderstorms) contain 2 or more cells, and are called multicell thunderstorms
- **squall line** - a line of thunderstorms
- sometimes a very large, rotating single-cell thunderstorm forms, called a **supercell** thunderstorm. They can cause 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

First

Squall Line Thunderstorms

LG 2b

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



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LG 2b

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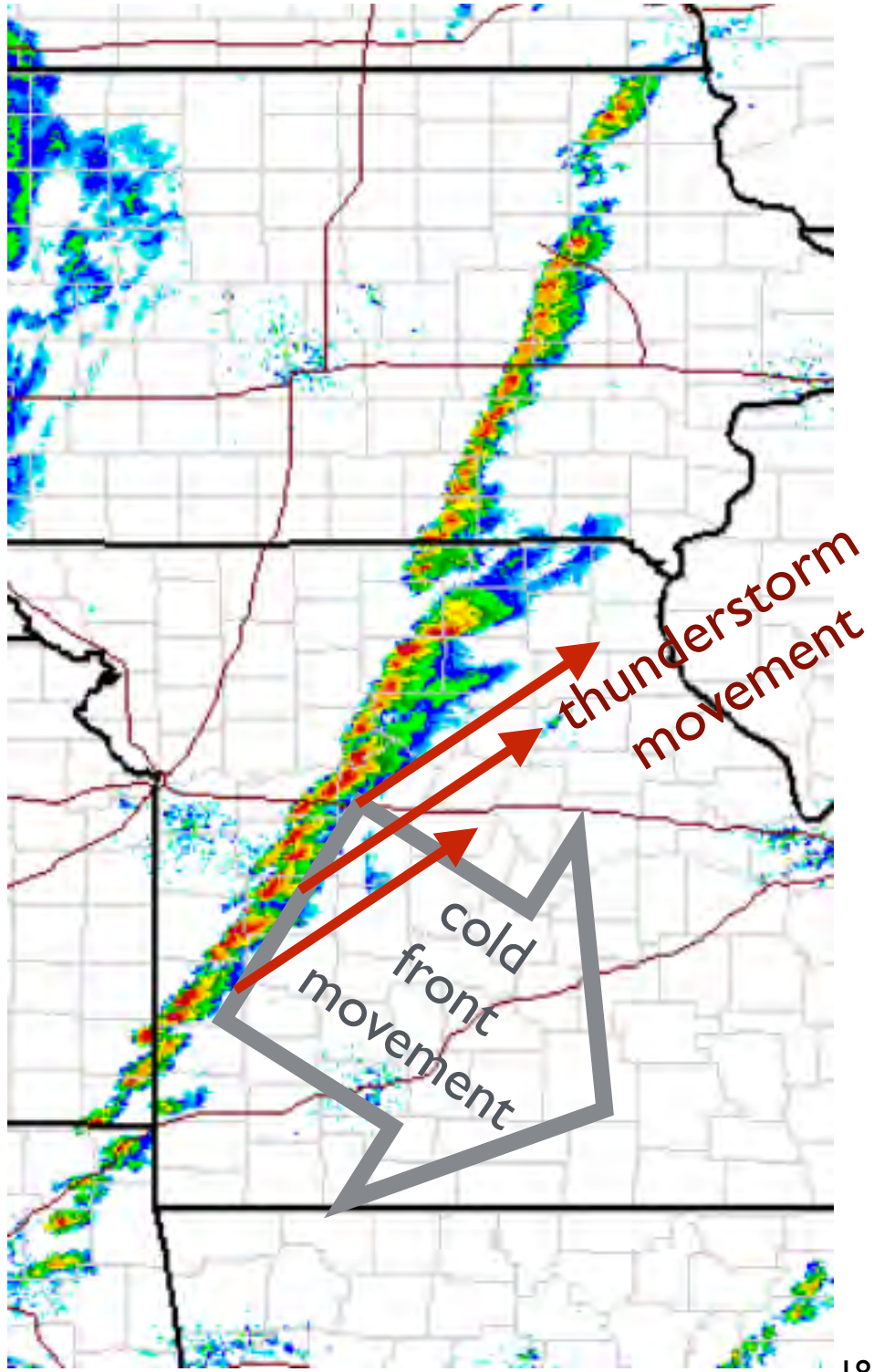

Squall Line Thunderstorms

LG 2b

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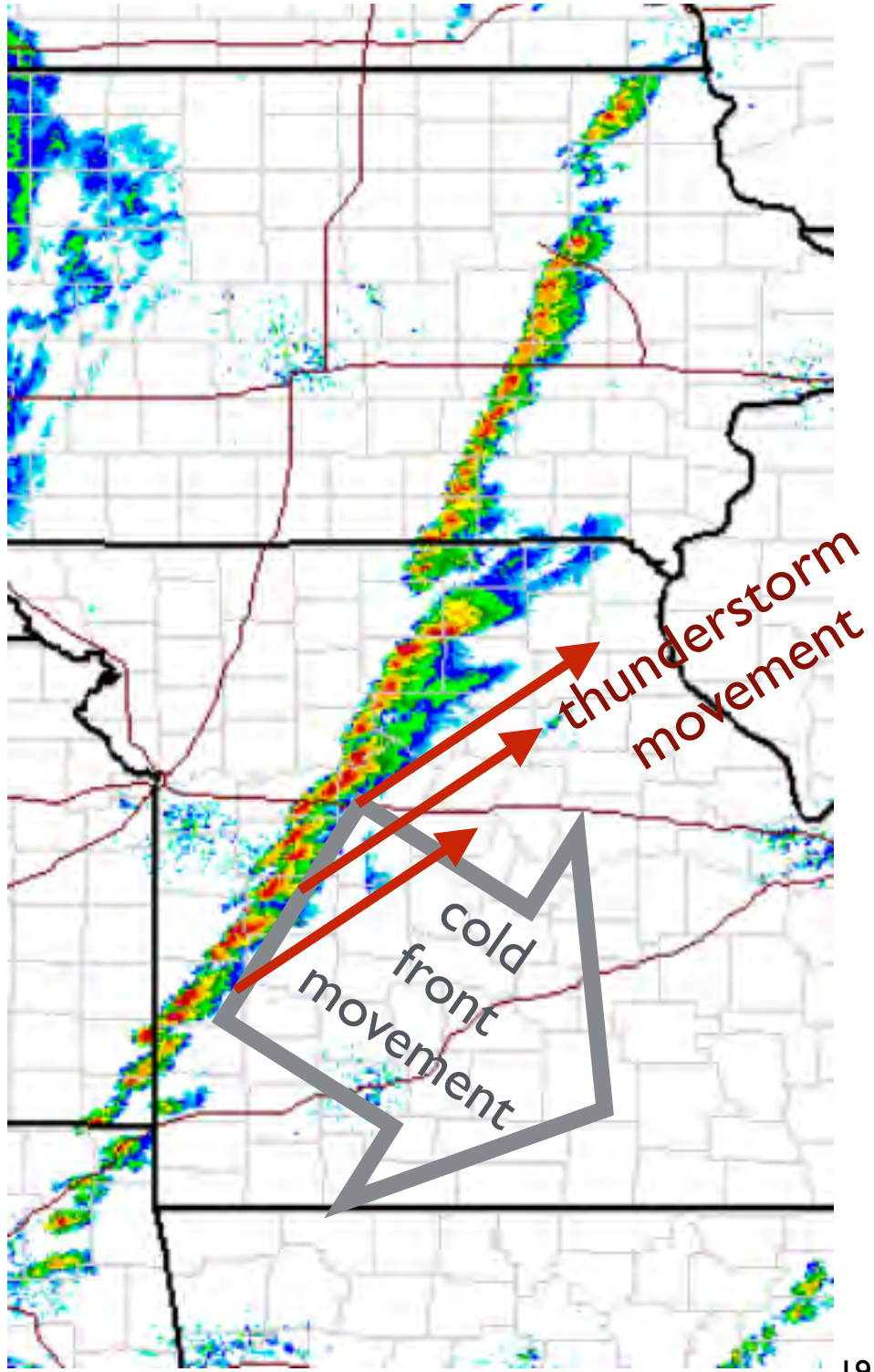
Video 2 - 07. Storm of Beauty (Pecos Hank , Watch only the **first 3:00 minutes**)

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



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- Supercell types:
  low precipitation , classical , high precip.

Next

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=yvIKIgeIY6g

Supercell Videos from YouTube

Three types of **supercell**:

(1) low precipitation (LP), but produce lots of hail.

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(3) high precip. (HP), updraft mostly surrounded by rain.

Some are in-between, and are called "hybrid" storms.

Day2-XX. LP Supercells in 2021. Pecos Hank. (show first 40 s)
https://www.youtube.com/watch?v=yL7Pyw-Rt1I

Watch on your own (Not testable):

Day2-XZ LP in 2020 (2:38 min)
https://www.youtube.com/watch?v=zzBylV2QkuI

Supercell Videos from YouTube

Three types of **supercell**:

(1) low precipitation (LP), but produce lots of hail.

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

(3) high precip. (HP), updraft mostly surrounded by rain.

Some are in-between, and are called "hybrid" storms.

Day2-25 Classic at Booker time lapse. 3 June 2013 (1:50)
https://www.youtube.com/watch?v=ak05BQ6eNLU

Watch on your own (Not testable):

Day2-20 Classic at Brisbane, Australia. Nov 2013 (2:30)
https://www.youtube.com/watch?v=o1eP5WVM5bQ

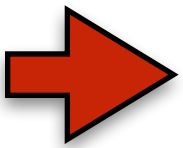
Day2-23 Classic mesocyclone in South Dakota, Aug 2017. (0:36)
https://www.youtube.com/watch?v=8rtBX09inw0

Supercell Videos from YouTube

Three types of **supercell**:

(1) low precipitation (LP), but produce lots of hail.

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



(3) high precip. (HP), updraft mostly surrounded by rain.

Some are in-between, and are called "hybrid" storms.

Day2-35 HP supercell in Texas. 2015
https://www.youtube.com/watch?v=trVMTXoDPGA

Hybrid Supercell. Watch on your own (Not testable):

Day2-30 Hybrid supercell in Lamar, CO timelapse. 2015
https://www.youtube.com/watch?v=L60AHze111o

1. Storm Hazards covered in this course

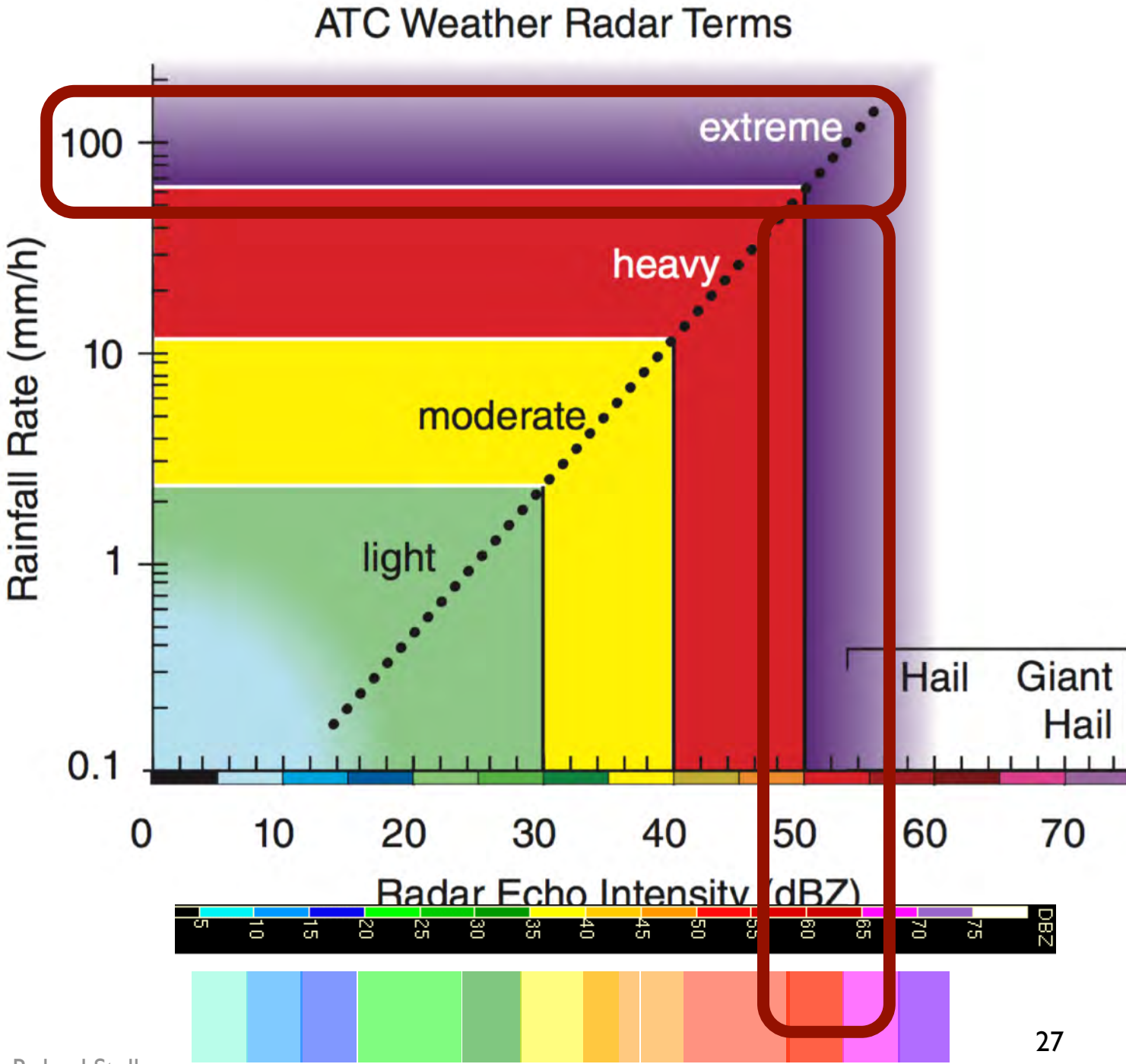
Thunderstorm Hazards

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

Hurricane Hazards

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

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



Flash Flood Safety

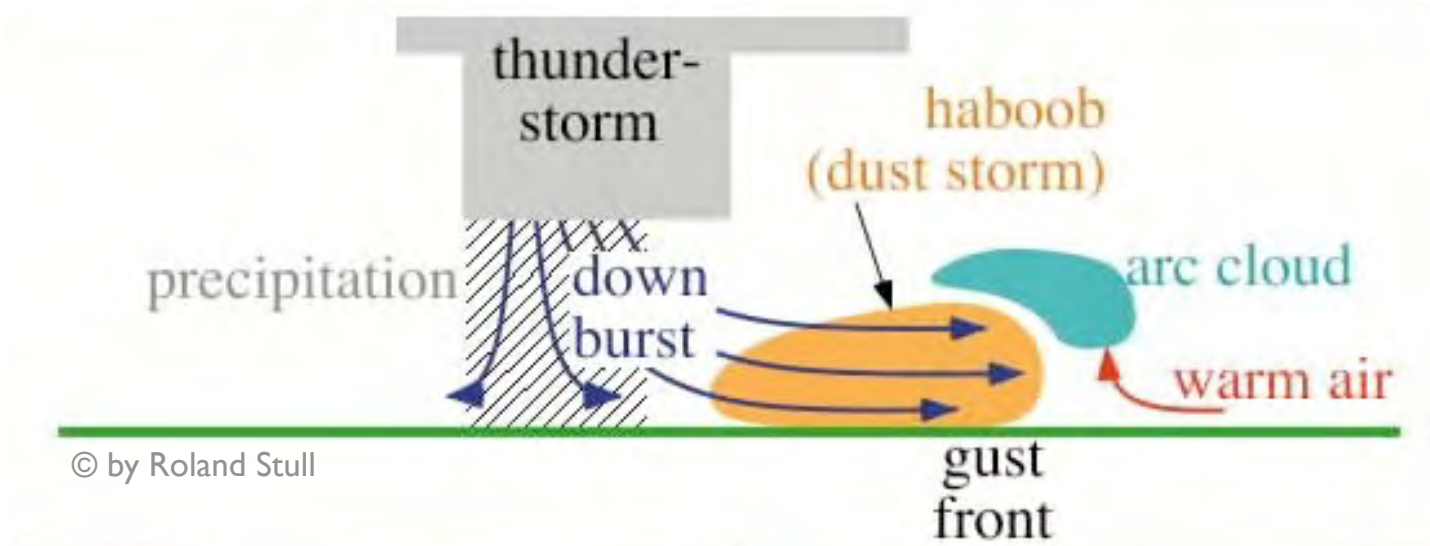
Day 2 Video 45:

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

https://www.youtube.com/watch?v=el6mIlHKrVY

Downbursts & Gust Fronts (of air)

Side view:



- 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

LG 2a,d, 4a

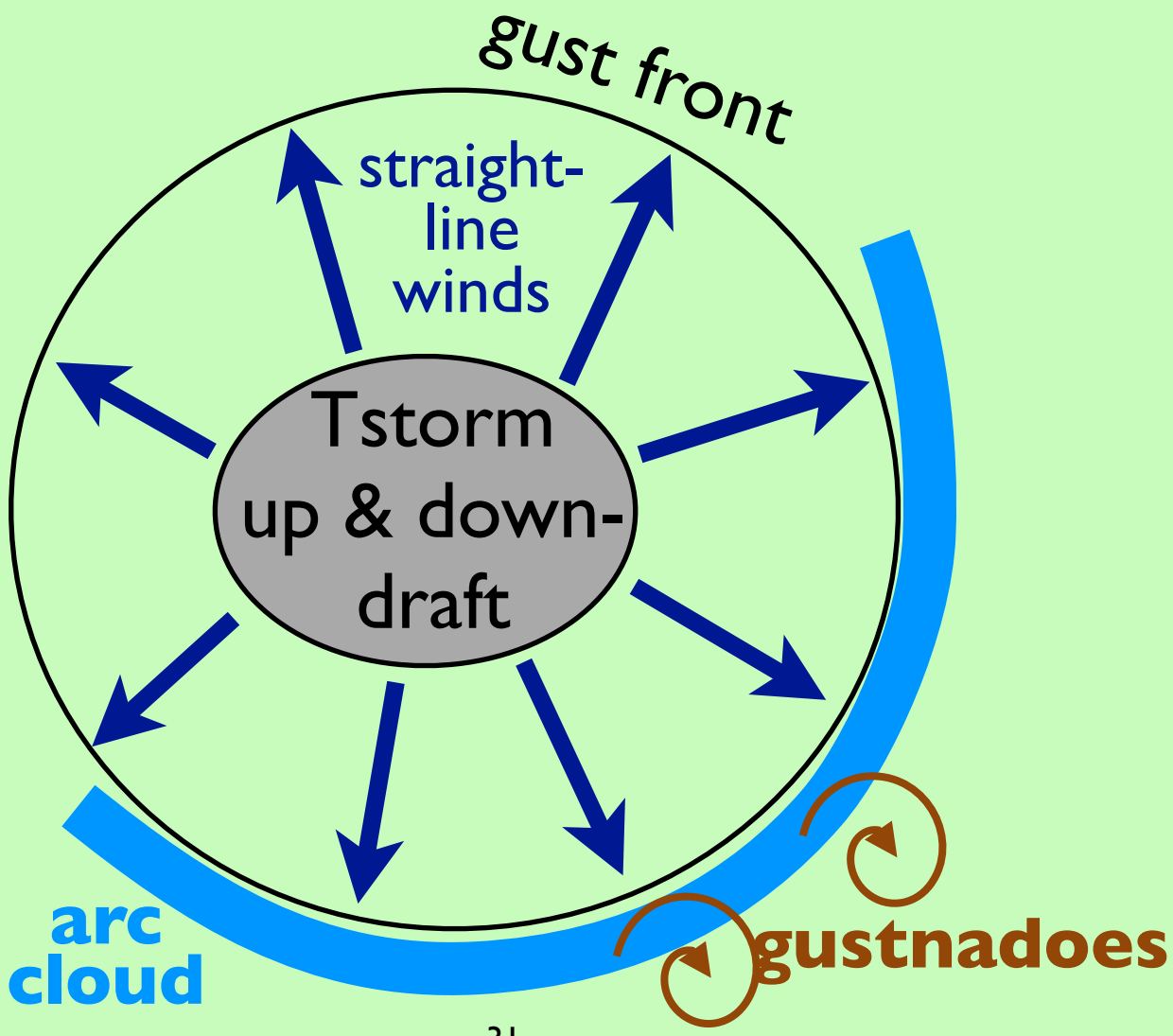
- What: Downburst - cold (dense) air sinking.
- Why: Tstorm can create dense air where **rain** falls; due to **evaporative cooling**.
- Risks: Often invisible, but a hazard to aircraft.

- 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)

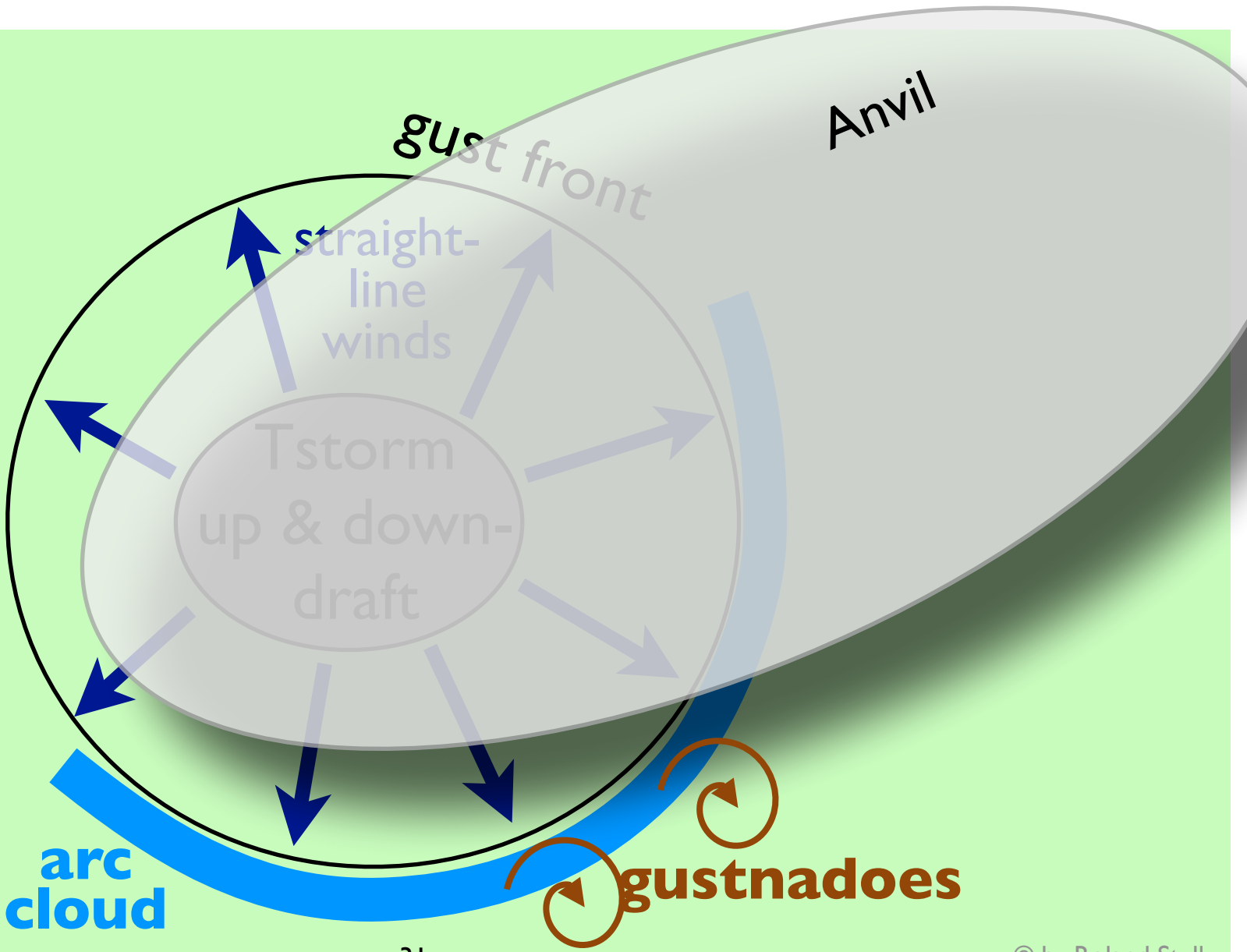
Top view:



ground

Downbursts & Gust Fronts (of air)

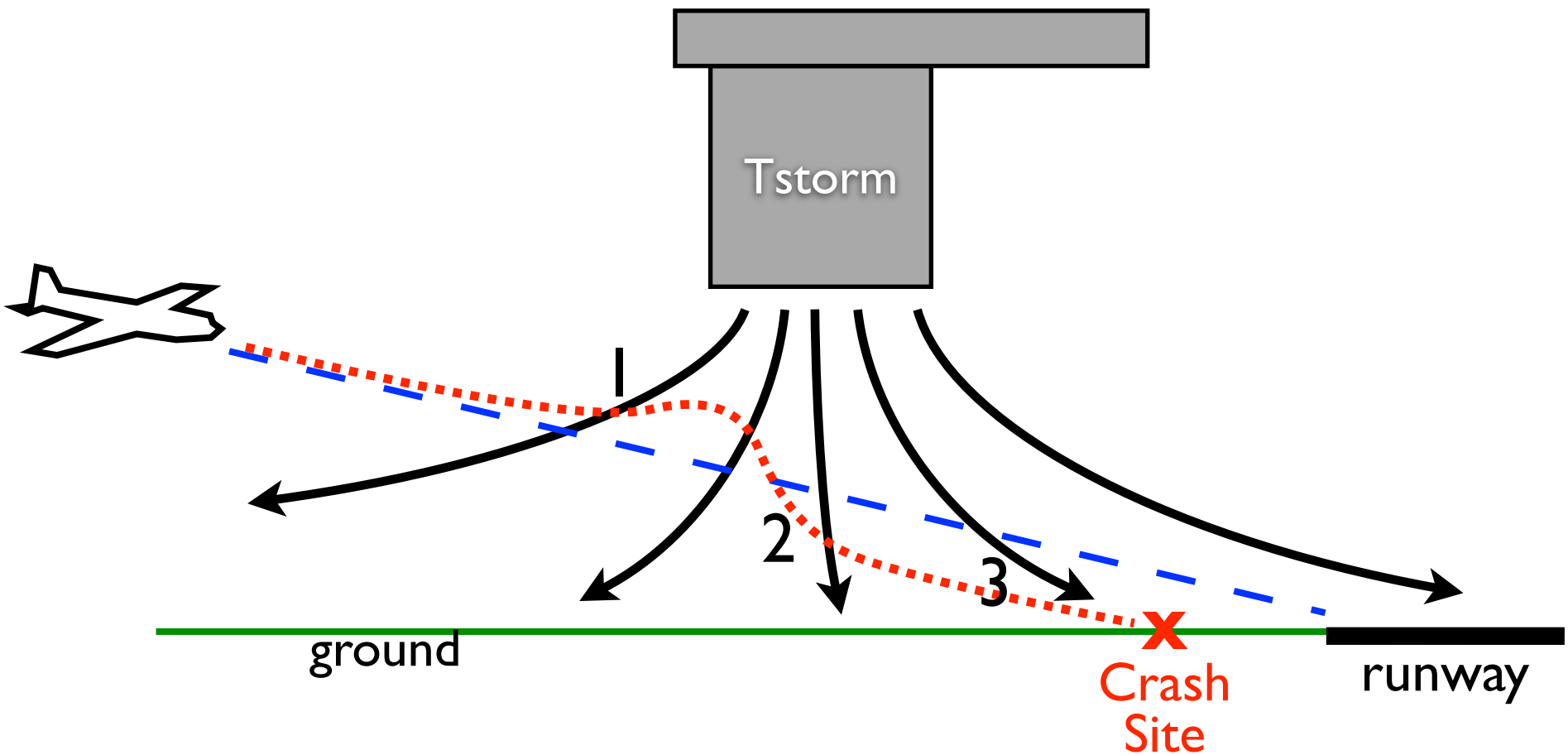
Top view:



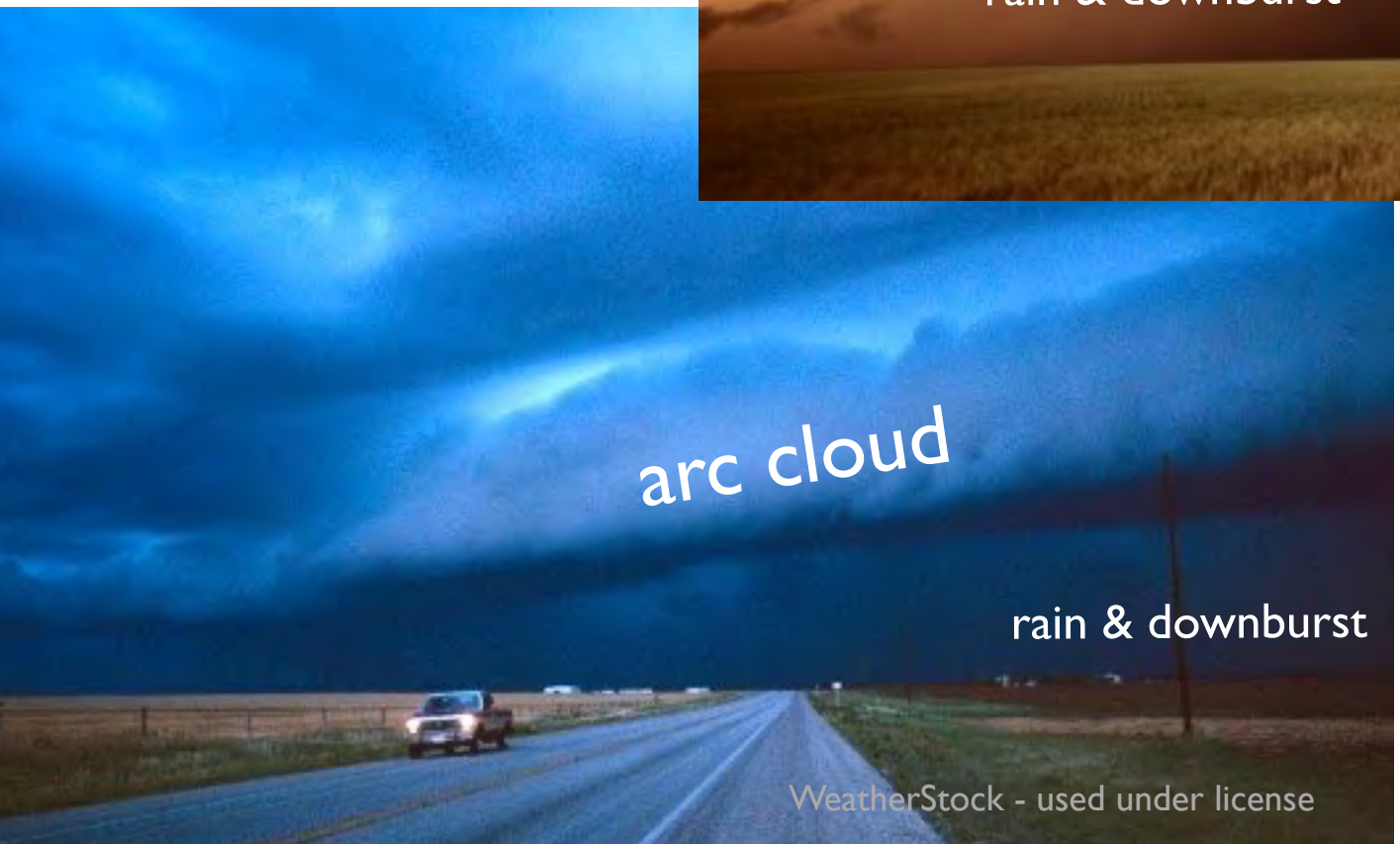
Downbursts & Gust Fronts (of air)

Crash of Eastern Airline Flight 66.

Killed 112 people at JFK airport in NY, 1975.



LG 2a,d, 4a



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

LG 2a,d, 4a

Another Hazard:

Haboobs
(sand storms)

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=iC2qIU8G8vw
- 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

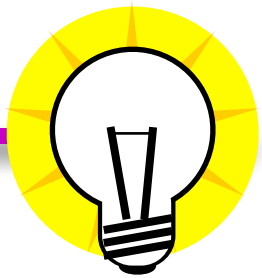
Stull vs. Downburst

cloud

virga

whitehorseair.com

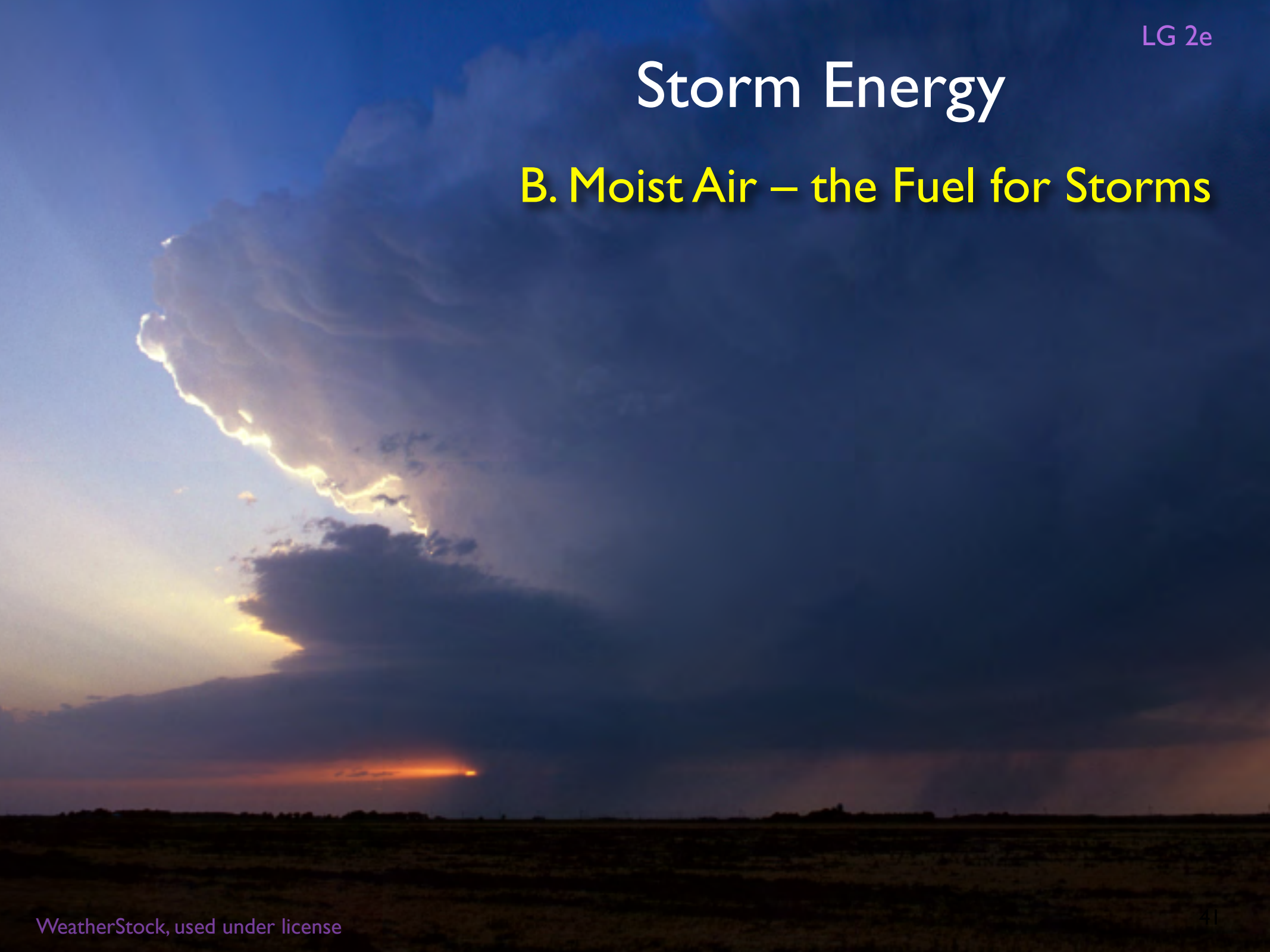
Insights



- 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,
- then to cause it to condense, &
- release its heat into the storm,
- resulting in precipitation & violent winds

Thus, we need to look at concepts of:

1. humidity
2. saturation
3. latent heat
4. advection
5. adiabatic cooling

1. Humidity

Air = mixture of gases:

- 0 to 4% of **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:

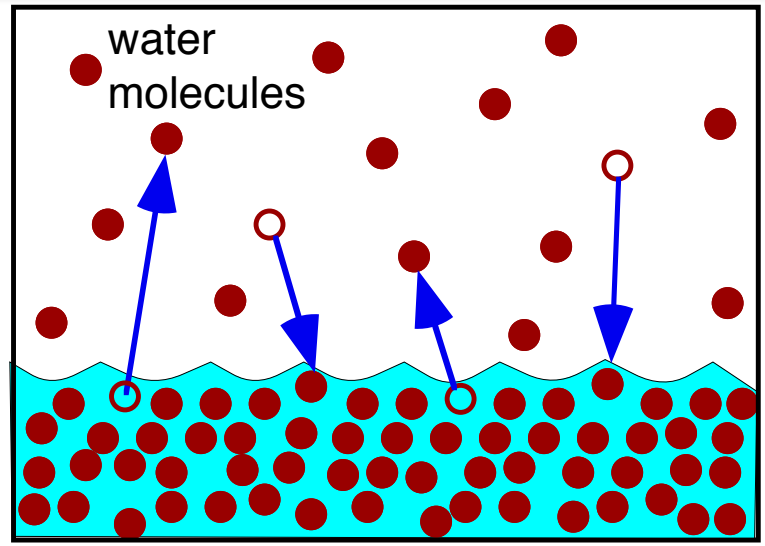
Examples.

(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

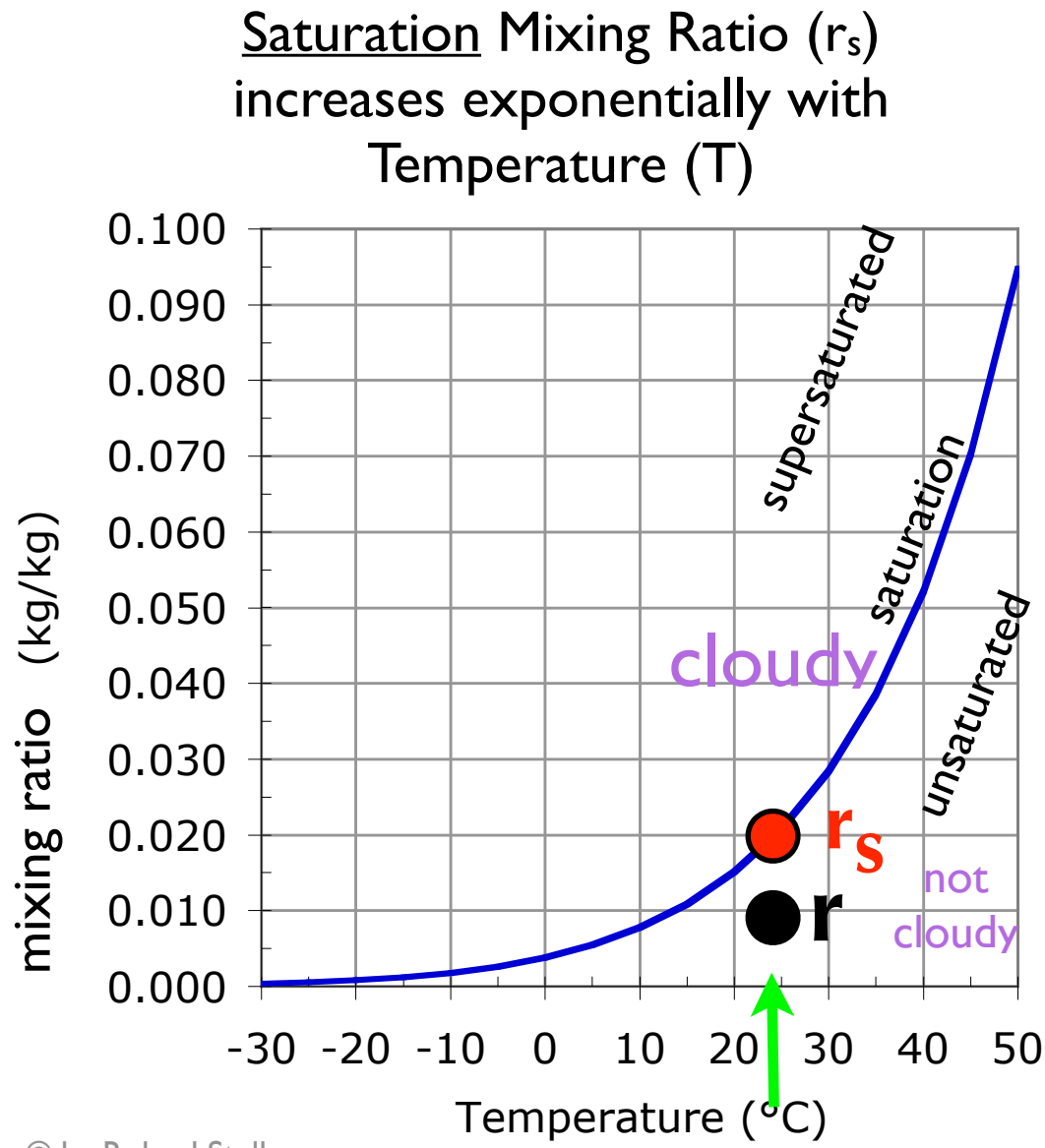


- Water vapour is special -> can easily **condense** into liquid.
- Constant exchange of H_2O molecules occurs between vapour & liquid:
  - (vapour to liquid) = **condensation**
  - (liquid to vapour) = **evaporation**
- The mixing ratio tends to approach an equilibrium where condensation matches evaporation. This equilibrium is called **saturation**.

- For all practical purposes, **saturation value is maximum humidity that air can hold** .

Saturation value is important in controlling atmospheric humidity.

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



Announcements

- If you are unable to download a copy of my lecture notes from Canvas, I put an extra copy of the notes at: https://www.eoas.ubc.ca/courses/eosc114/

3. 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 thermal cools roughly 10°C/km of rise.

- Cooler air can hold less water as vapour

- Therefore, some vapour must condense into liquid droplets.

- But condensation releases latent heat.

WeatherStock, used under license

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:

- releases the stored **latent heat** back into sensible heat to make storms warmer,
- reduces the humidity down to the equilibrium (saturation) value, &
- produces or increases liquid cloud drops, which can grow to become **rain** drops.

The Turbulent Atmosphere

Prof. Roland Stull

Summary of Day 2

- More Thunderstorm Fundamentals
  4. Squall-line & Supercell thunderstorms & mesocyclones
  5. Observing Thunderstorms, with satellite & radar
- Downpours, Downbursts & Gust Fronts
- Moist air – the fuel for storms

Next Class

- Tornadoes