

ATM S 103

# Hurricanes and Thunderstorms

Their Science and Impacts





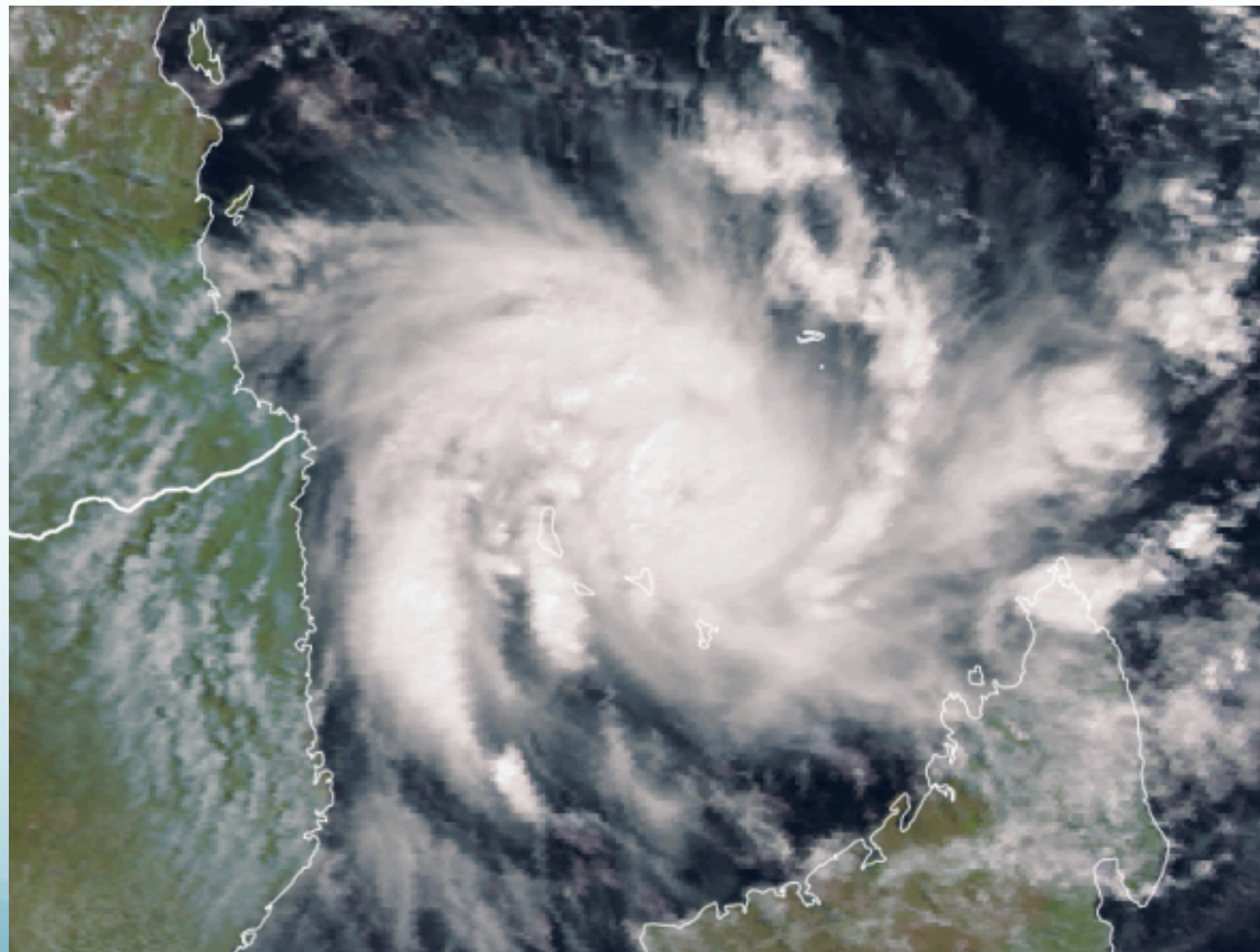
# Midterm 1: Wednesday May 1

- Bring a **Scantron** form
- Closed book, notes, electronics
- 30 multiple choice questions (similar to homework)
- Covers
  - Homeworks 1-3
  - Lectures through today
  - Reading weeks 1-4
- **Clue review session:** Thursday (tomorrow) April 25, 6:30-8:00 PM in MGH 231

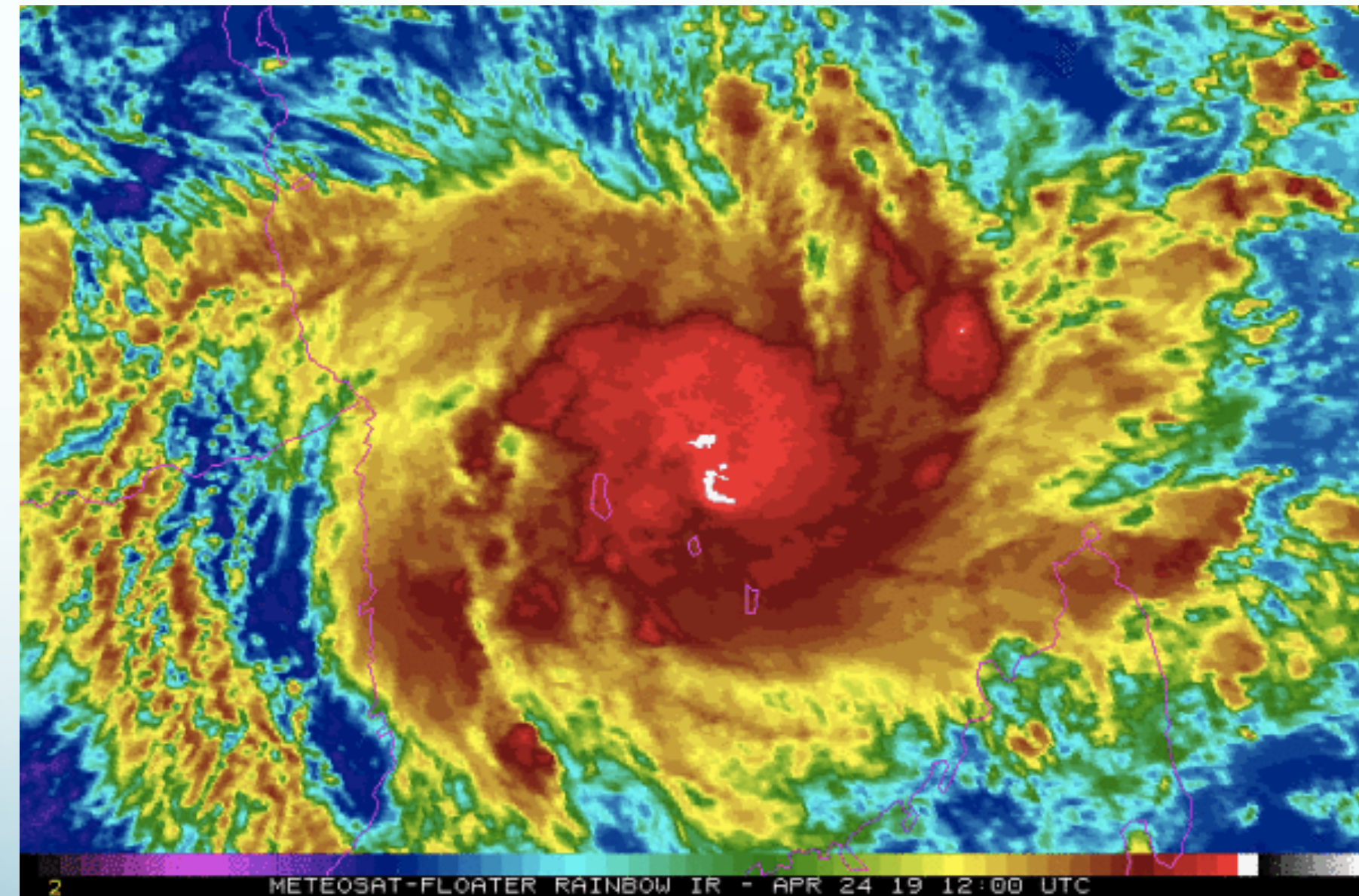


About a month after Idai,  
another tropical cyclone heading toward Mozambique

- Tropical cyclone Kenneth (140 kph or 85 mph)
- <https://www.cnn.com/2019/04/24/africa/storm-kenneth-mozambique-intl/index.html>



Satellite image of a Tropical Storm Kenneth near Madagascar on Tuesday, April 23. (EUMETSAT)



Satellite image showing Kenneth strengthening near Comoros on Wednesday, April 24. (NOAA)



# Topics for today

- Flash floods
- Formation of rain drops
  - Collision and coalescence
  - Supercooled water
  - Ice crystal process
- Hail

# Hazards from single-cell thunderstorms

- Lightning
- Downdrafts and the spreading gust front create microbursts, an aviation hazard.
- *Flash floods*

# Flash Floods

# W Concerning U.S. flash flood fatalities

Almost 50%  
are vehicle  
related

Majority are  
male

Both of the  
above

# Answer

- Almost 50% of the flash-flood fatalities are vehicle related and the majority are male.

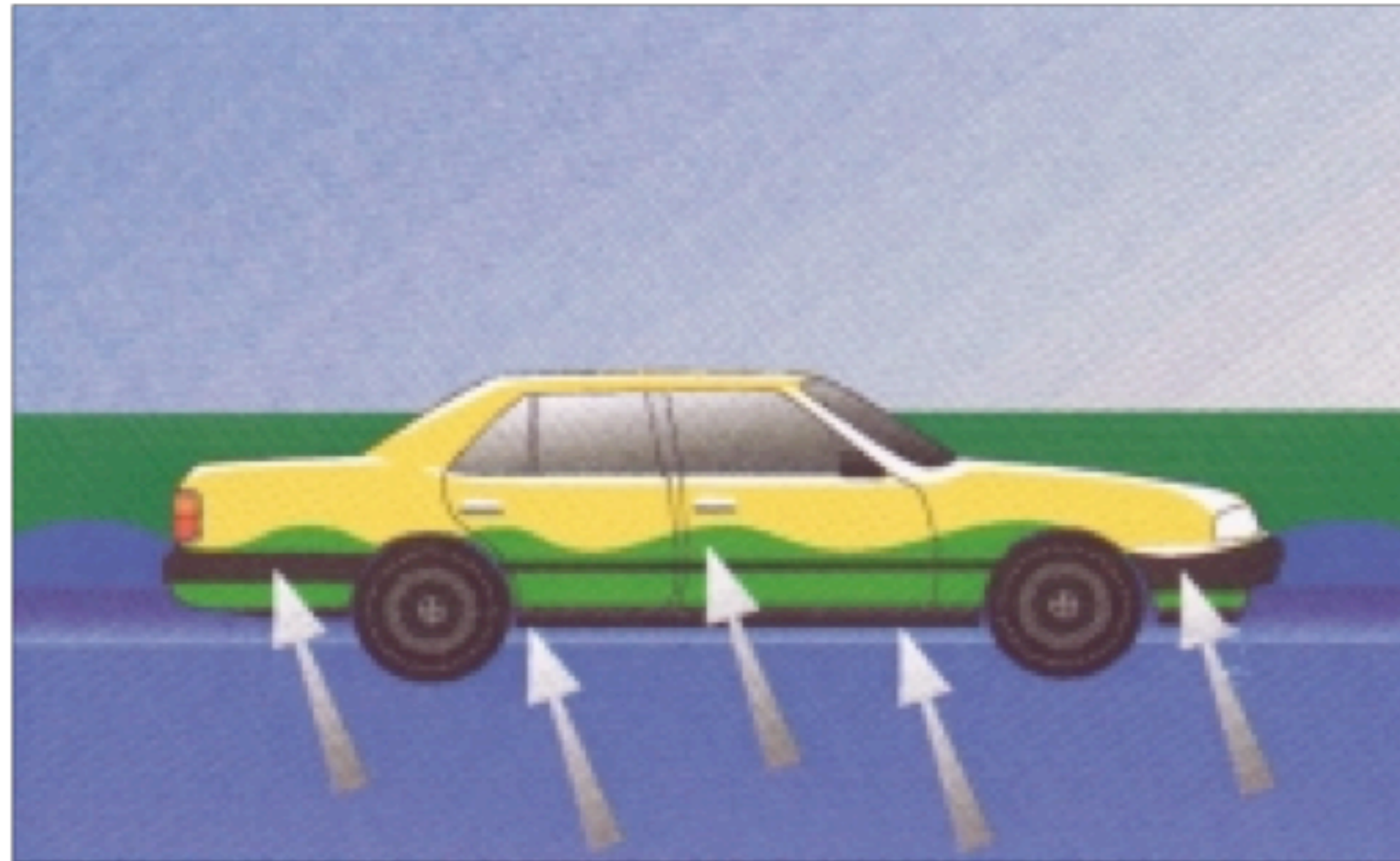


# Cars and Flash Floods

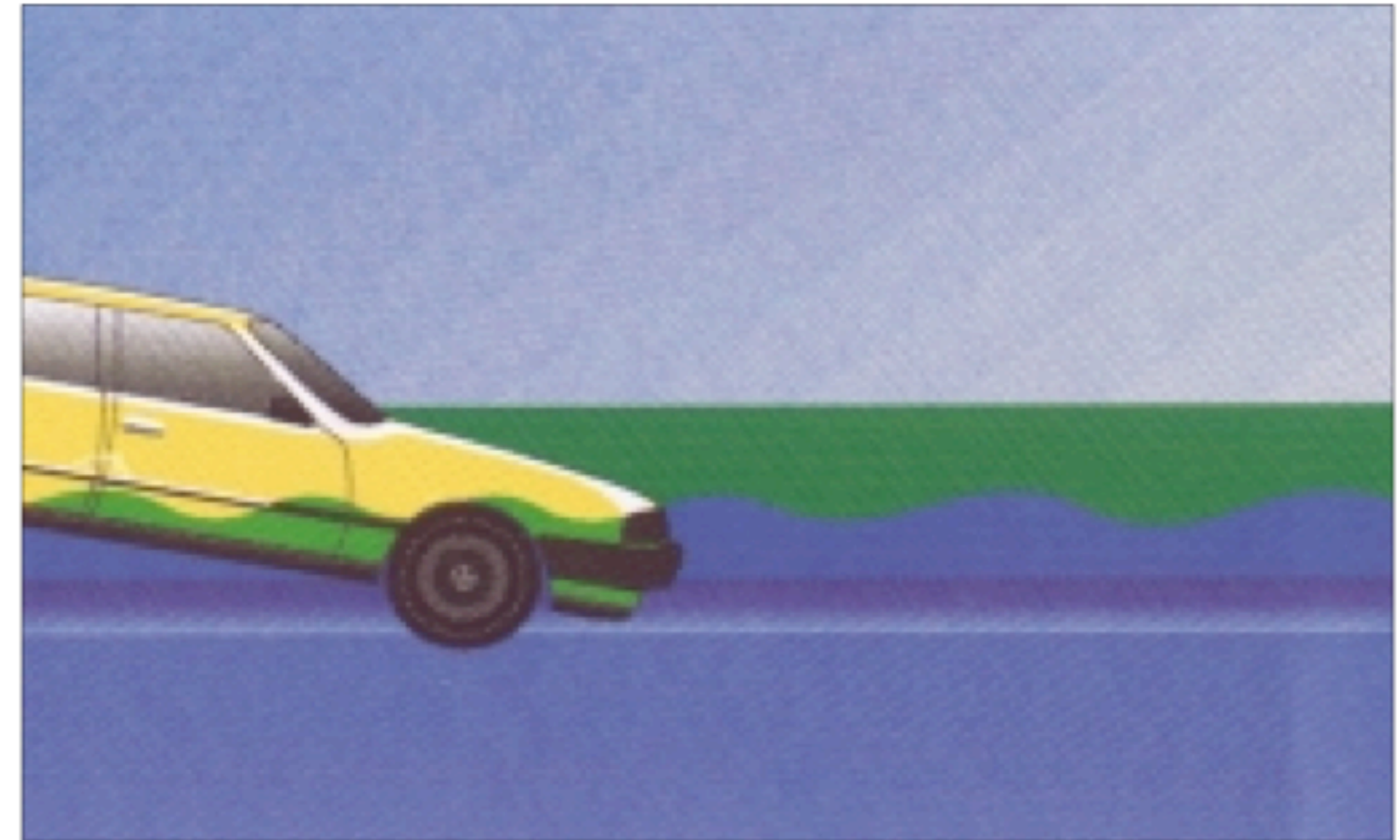
A truck goes for it

Toowomba, January 10, 2011

# Cars and Buoyancy



But the biggest factor is buoyancy. For each foot the water rises up the side of the car, the car displaces 1,500 lbs. of water. In effect, the car weighs 1,500 lbs. less for each foot the water rises.



***Two feet of water will carry away most automobiles.***



# “Flash” Flood

Mill Creek, Green Sulphur Springs, West Virginia

# “Flash” Flood

August 24, 2012 Southern Utah



# July 31, 1976

## Big Thompson Canyon, Colorado

- Flash flood triggered by nearly stationary thunderstorms near the upper section of the canyon that dumped 12 inches of rain in less than 4 hours.
- Little rain fell over the lower section of the canyon, where many of the victims were.
- About 9 p.m., a wall of water 20 ft high raced down the canyon at 14 mph, destroying 400 cars, 418 houses and 52 businesses and washing out most of the road.
- 139 were killed, 5 others were never found



# Big Thompson Flash Flood





# Aftermath

- Public education
- Some flood prone areas not rebuilt; river given more room to expand.





# Big Thompson Canyon, September 15, 2013





# Formation of Raindrops

# Virga

- <https://www.youtube.com/watch?v=FC3gJ4Kob8g>



# Virga





**Virga** is rain that never reaches the ground





# W Virga is rain that never reaches the ground because it

Gets caught in  
a updraft.

Evaporates

Turns into hail

# Answer

Virga is rain (or snow) that evaporates (or sublimates) while falling through dry air before reaching the ground.

Virga is more common when the air below cloud base has low relative humidity.



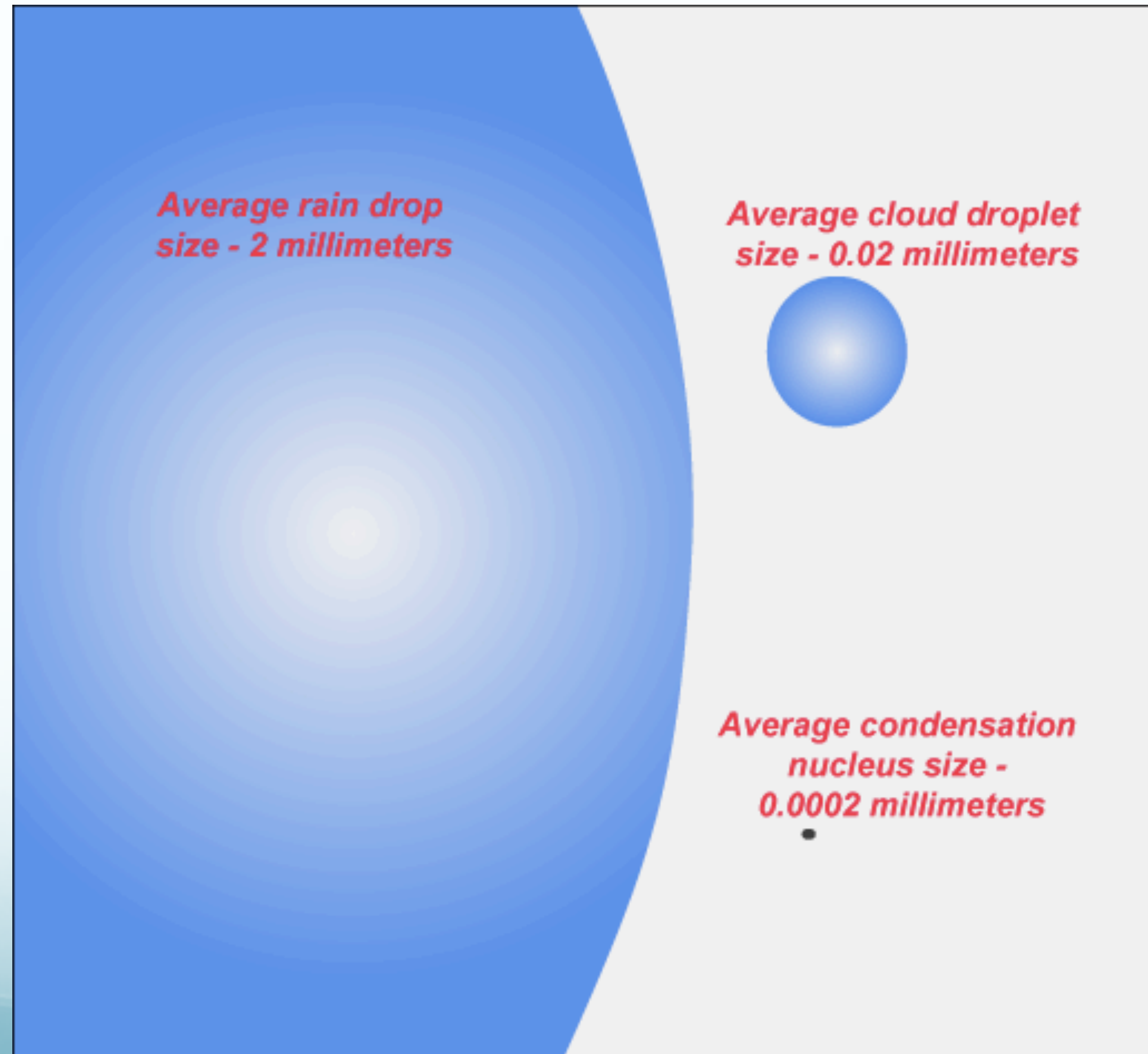
# What makes it a “raindrop”?

Size comparison (diameters)

- Cloud droplet: 0.02 mm (typical)
- Human hair 0.04 – 0.12 mm
- Drizzle drop: 0.2 – 0.5 mm (by definition)
- Raindrop: 0.5 – 8 (?) mm
- 2 mm raindrop is **1 million** times heavier than a 0.02 mm cloud droplet



# Size comparison





# W What limits the maximum size of the very largest raindrops?

The time available for it to grow before it hits the ground.

Competition for water vapor from nearby drops.

Aerodynamics.

# Answer: Aerodynamics make

Vertical wind tunnel experiment



# What does a raindrop look like?



# Aerodynamic Drag on a Large Raindrop





# Terminal Velocities

(at which aerodynamic drag balances gravity - no acceleration)

Object	Diameter (mm)	Terminal vel. (m/s)
Cloud droplet	0.02	Almost zero
Drizzle drop (Seattle winter rain)	0.2	1
Small raindrop	1	4
Large raindrop (thunderstorm rain)	5	10
Large hail	20	20
Skydiver	?	55

# **W** Why is rain from thunderstorms often made of larger raindrops than the average Seattle wintertime raindrop?

Because thunderstorms have very strong updrafts.

Because thunderstorms are short lived.

Because of the winds at the gust front.



# Answer

- Unstable air in thunderstorm updrafts rises much more rapidly than in most clouds.
- *Strong updrafts are required to keep precipitation particles aloft until they grow large in size.*
- When thunderstorm rain is not heavy, it may be because precipitation below cloud has
  - Evaporated enough to leave only small residual droplets.

# Terminal Velocities

(at which aerodynamic drag balances gravity - no acceleration)

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# How do raindrops get big enough to fall?

- Typical raindrop contains 1 million times the water in a typical cloud drop.
- **Condensation** of vapor on the surface of a liquid droplet **increases its mass**
  - Rapidly when the droplet is very small
  - Very slowly when the droplet is large
- The droplet's diameter grows more slowly as the ratio of its surface area to its volume gets smaller.

# Growing a Raindrop

- At least **2 days** are required to grow a 2 mm raindrop solely by condensing water vapor on its surface.
- But clouds can develop and start to rain in less than 1 hour!
- How do raindrops grow so quickly?
  - Through a process involving **ice crystals**
  - And/or through **collision and coalescence**



# Collision and Coalescence

- Large droplets fall faster than small droplets
- The large droplets may collide with smaller droplets in their path
- If **collisions result in a merger**: the drops **coalesce**
- Coalescence is not automatic
  - Drops may bounce off each other
  - Chances of a merger are enhanced if the droplets have different electrical charges.

# Collision and Coalescence

Vertical wind tunnel experiments



## Where do the first large drops come from?

- They start large because they form on large CCN.
- Turbulent air motions cause similar sized droplets to collide and coalesce into a few larger droplets.

# Ice Crystal Process



# Cloud edges: Liquid droplets distinct; ice fuzzy





# Why Does the Cloud Edge Look Different?

- Water droplets evaporate more rapidly than ice crystals when they are mixed outside the edge of the cloud.
- So the cloud boundary appears sharper when only liquid droplets are present.
- Why does it matter? Once ice forms in deep cumulus clouds, rain is on the way.