

# Tornados

Feng Hanyi and Zhang Bowen Kellie



# CONTENTS PAGE

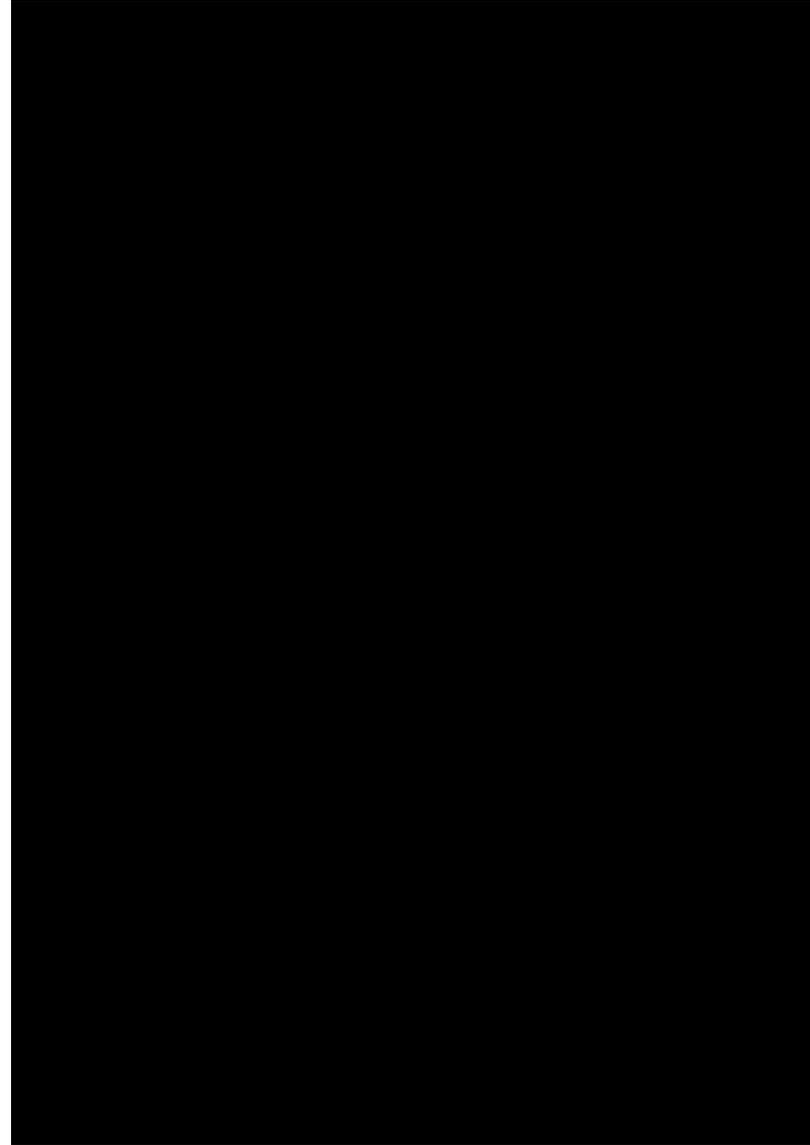
1. Formation of Tornadoes
2. Physics concepts involved in the formation of Tornadoes
3. Detection of Tornadoes
4. Extra physics concepts involved in large masses of rotation

# PHYSICS CONCEPTS TO UNDERSTAND

1. Wind Shear
2. Formation of updrafts by convection
3. Angular Momentum Conservation
4. Coriolis Force
5. Doppler Effect

# Tornados

- Formed in Supercell thunderstorms
- Common type of tornado
- Top-down process formation



# Formation of clouds

- Hot moist air rises
- Usually: forms shallow clouds
- Unstable atmosphere: Rises to form cumulonimbus clouds
  - Dense, dark
- Forms supercell thunderstorms



1000 m altitude > 60 km/h from west

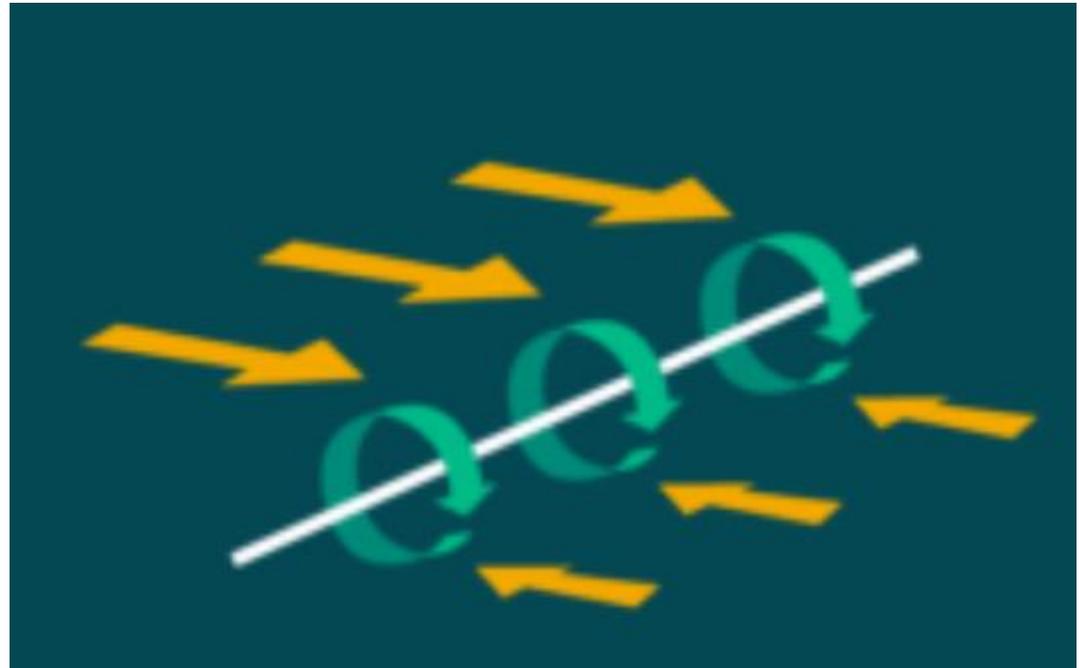


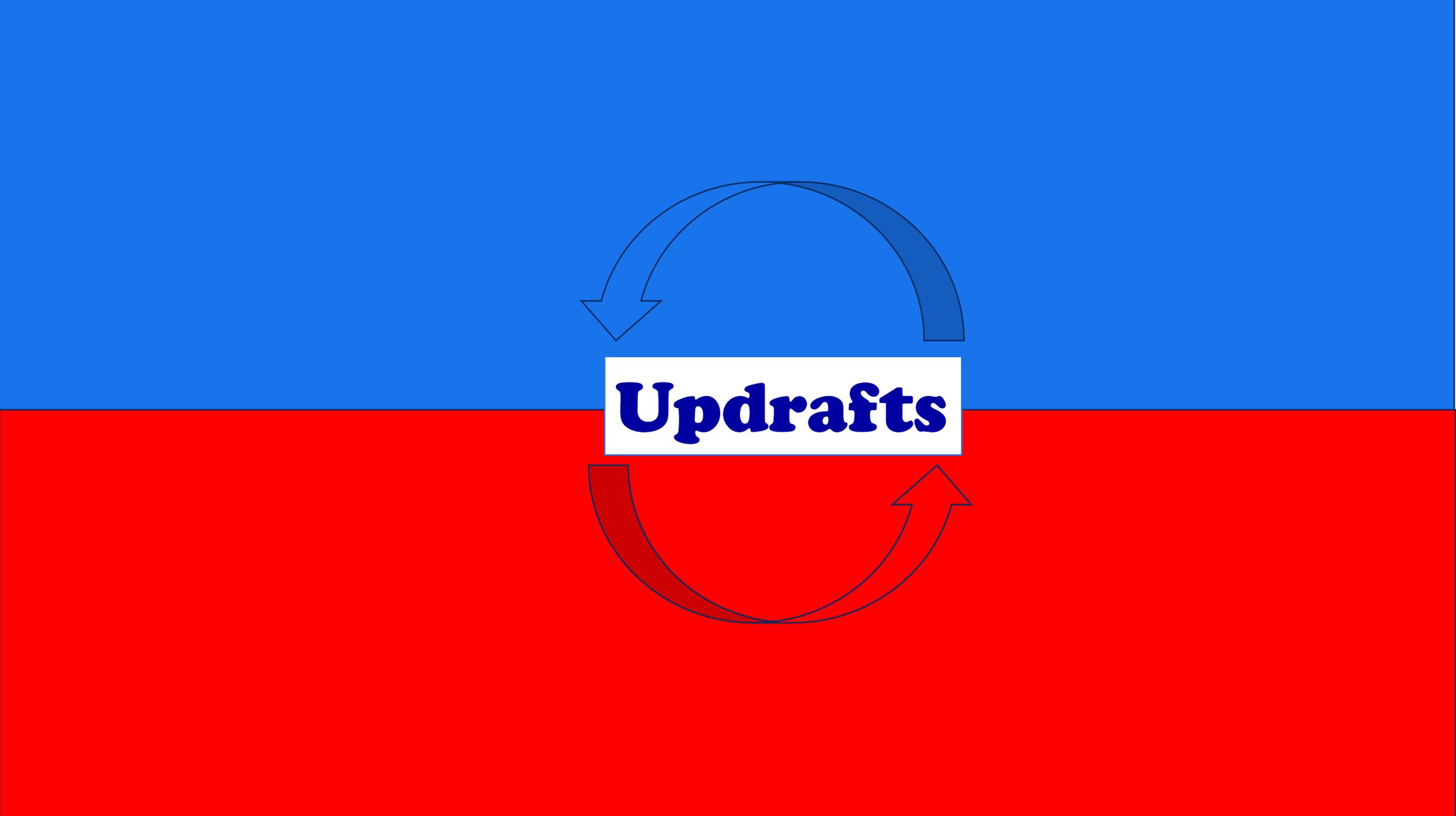
0 m altitude > 30 km/h from south

# Wind Shear

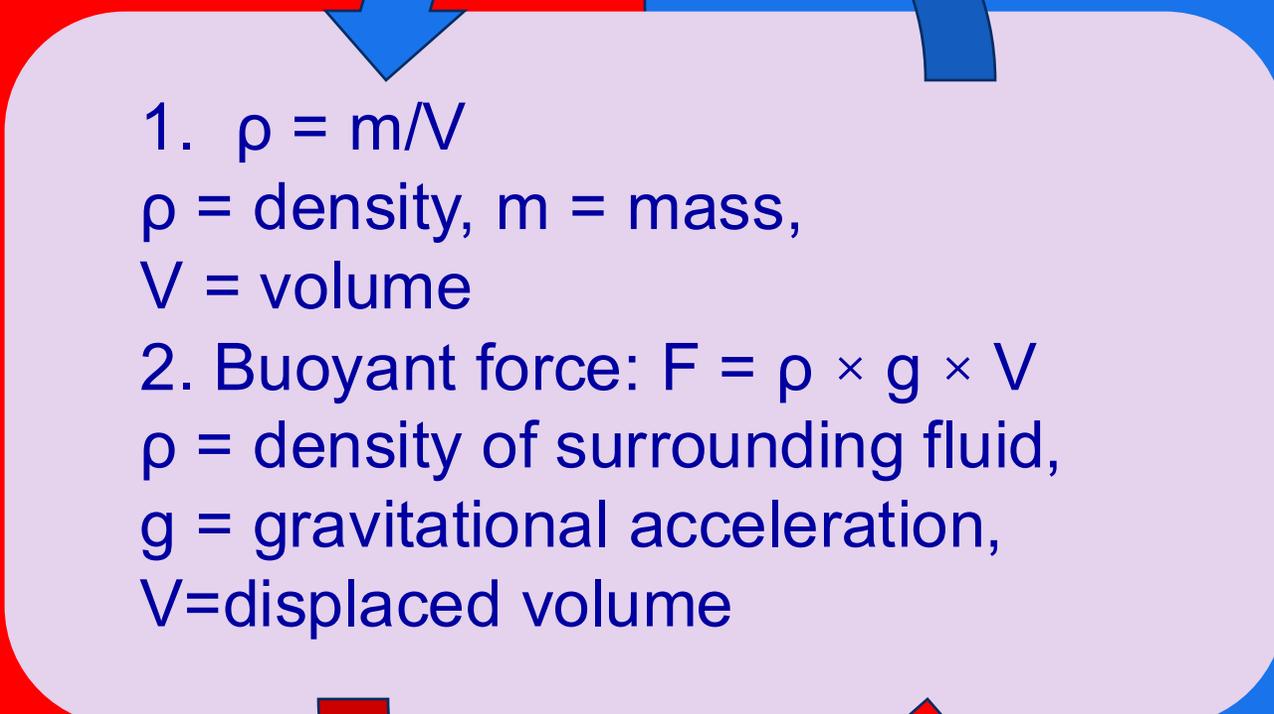
Wind shear = change in **wind speed** or **direction** with **height**

**Creates horizontal rotation in atmosphere**





**Updrafts**



1.  $\rho = m/V$

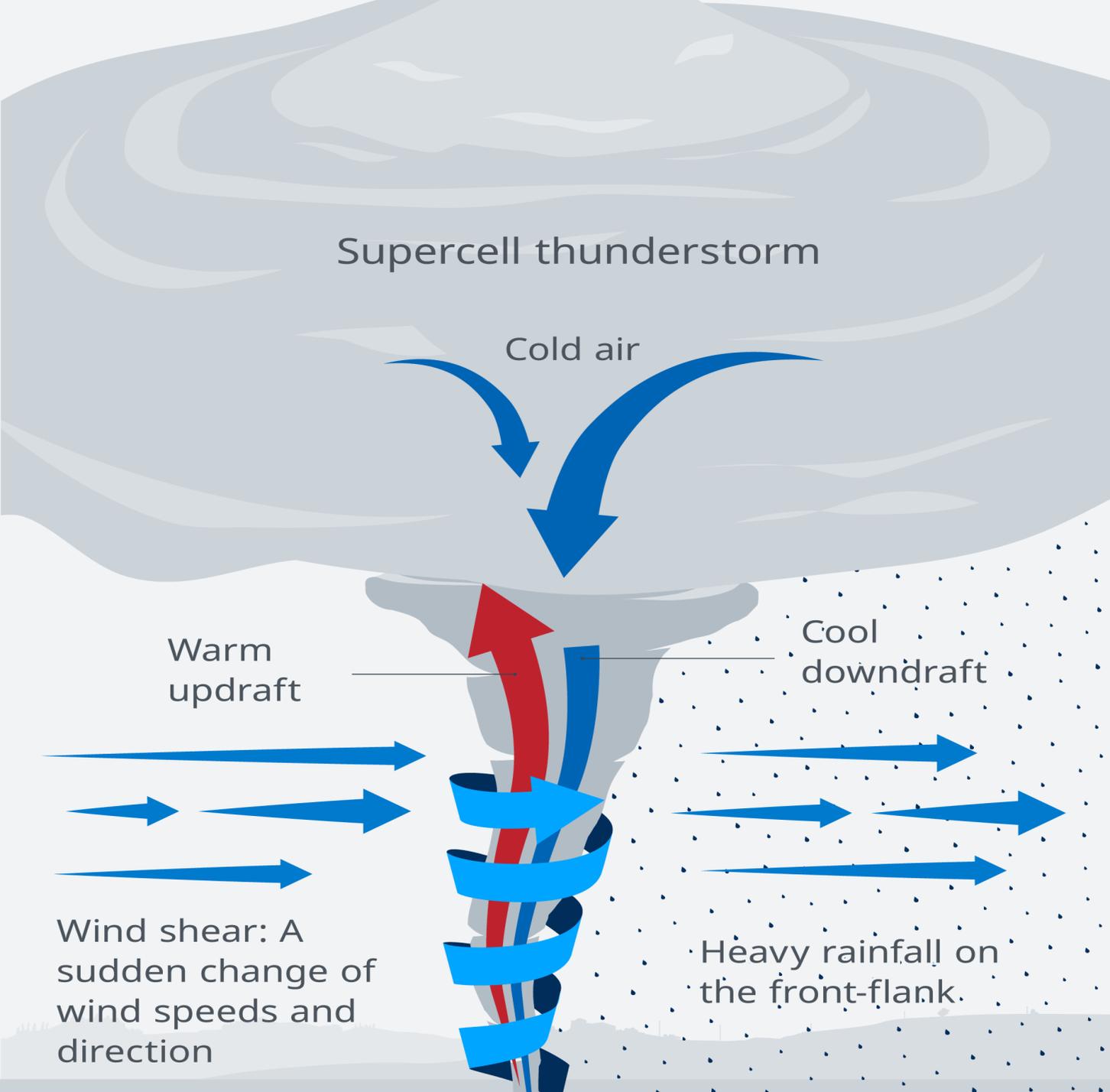
$\rho$  = density,  $m$  = mass,  
 $V$  = volume

2. Buoyant force:  $F = \rho \times g \times V$

$\rho$  = density of surrounding fluid,  
 $g$  = gravitational acceleration,  
 $V$  = displaced volume

## **Strong convection wave lifts the horizontal vortex**





**Downdraft:**  
rain/cool air

- Air wraps
- Focused rotation
- Small area

# Destruction

Initial:  $r_1 = 1000\text{m}$ ,  $v_1 = 50$   
km/h

Final:  $r_2 = 100\text{m}$ ,  $v_2 = ?$

$v_2 = 50 \times (1000/100) = 500$   
km/h

$$L = mvr$$

Conservation of angular momentum

$$mv_1r_1 = mv_2r_2$$

$$v_1r_1 = v_2r_2$$

Therefore:  $v_2 = v_1(r_1/r_2)$



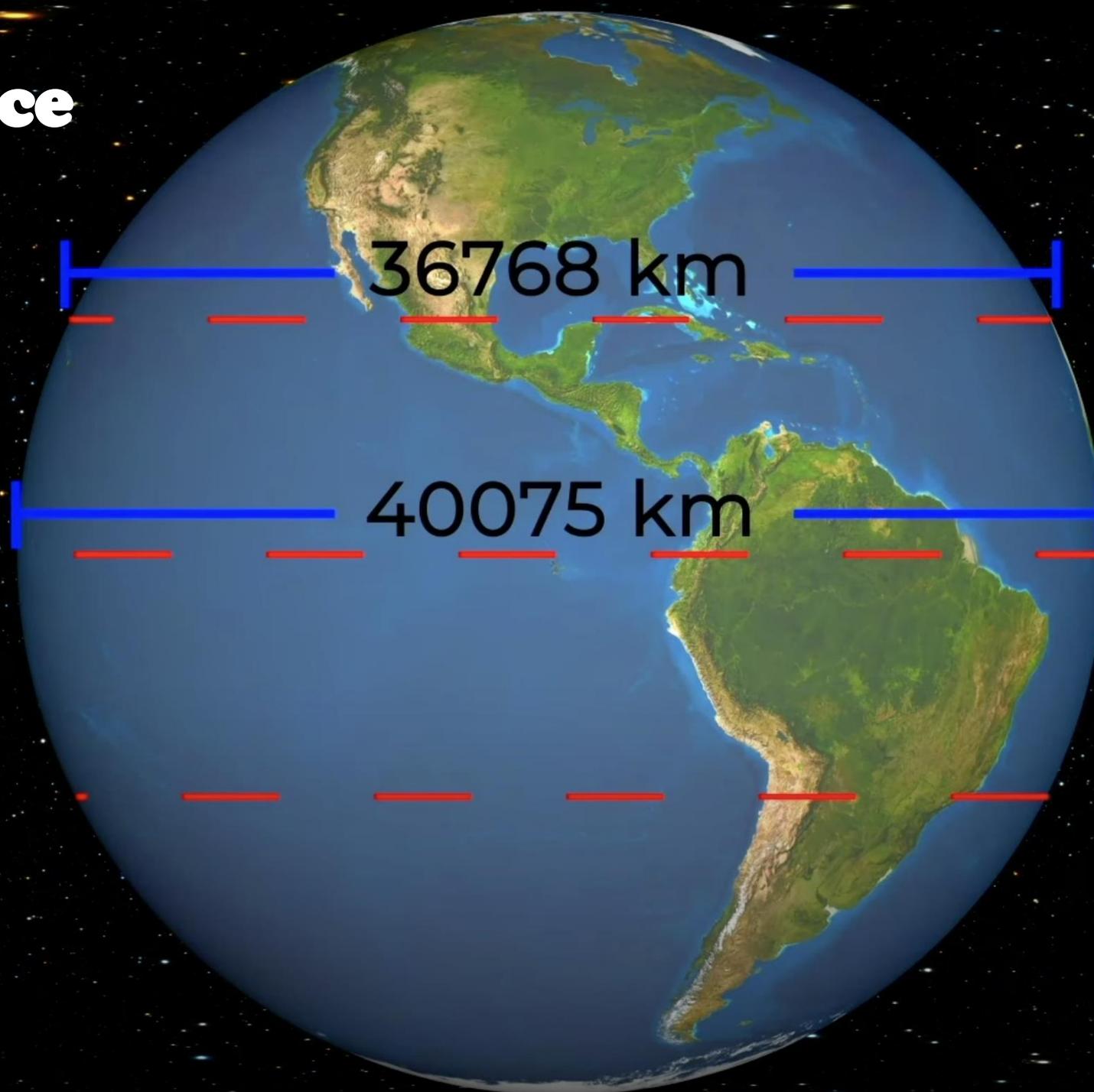


## **Gaspard-Gustave de Coriolis**

- French physicist
- Discovered the Coriolis effect
- when researching on a body on a rotating surface, the general effects of motion still apply to the body
- claimed that there must be the addition of a new fictitious force acting on the body for general equation of motion to still be mathematically correct
- *Presented his ideas in Sur les équations du mouvement relatif des systèmes de corps*(On the equations of the relative motion of systems of bodies)

# Coriolis force

- Diameter of earth is longest at equator



# Coriolis force

- Diameter of earth is longest at equator
- Rightward deflection in the Northern Hemisphere and leftward deflection in the Southern Hemisphere

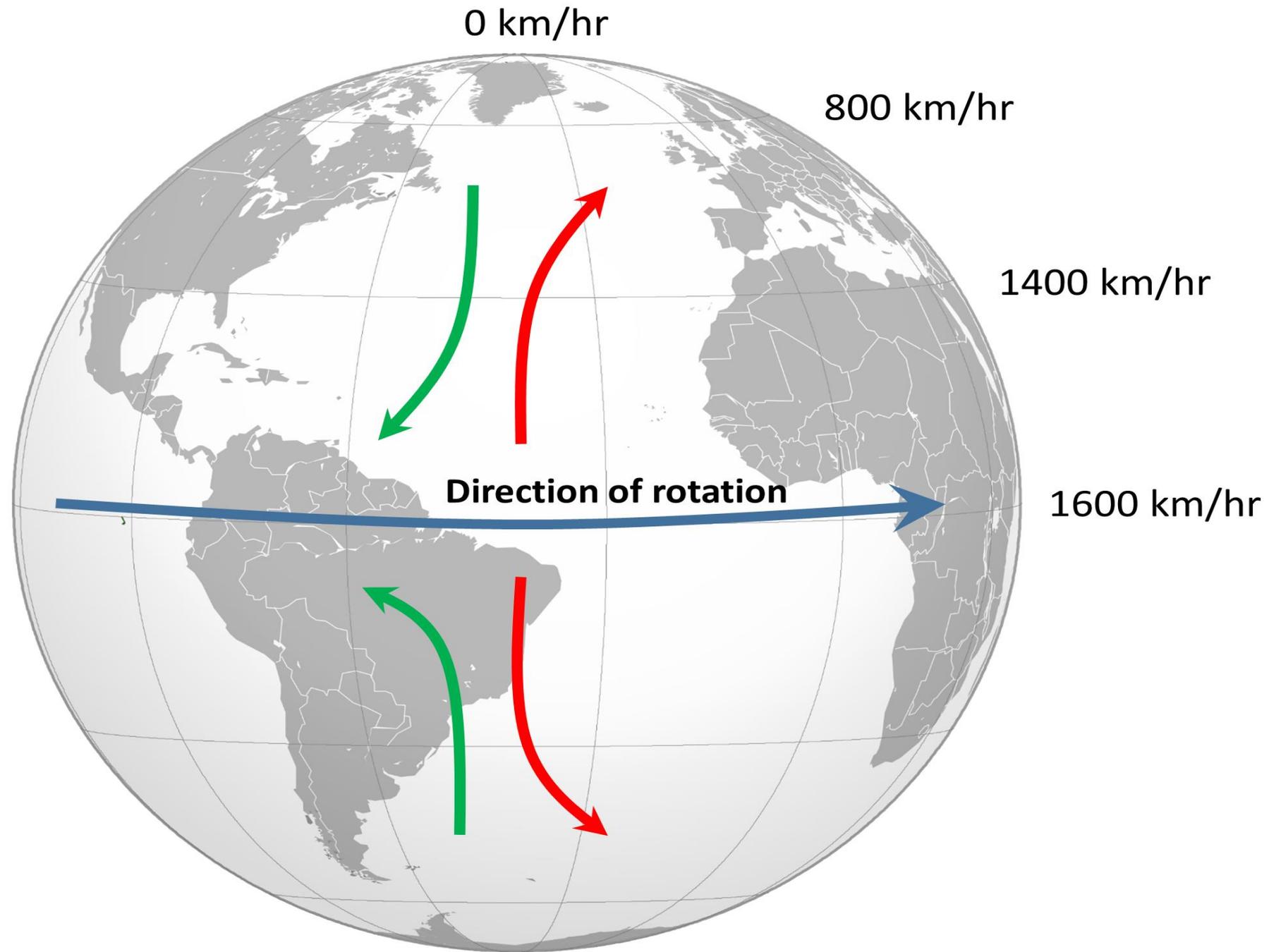
$$F_C = -2m(\boldsymbol{\Omega} \times \mathbf{v})$$

$F_C$  = coriolis force

$m$  = mass

$\boldsymbol{\Omega}$  = angular velocity

$\mathbf{v}$  = tangential velocity



In the **Northern Hemisphere**, it flows 



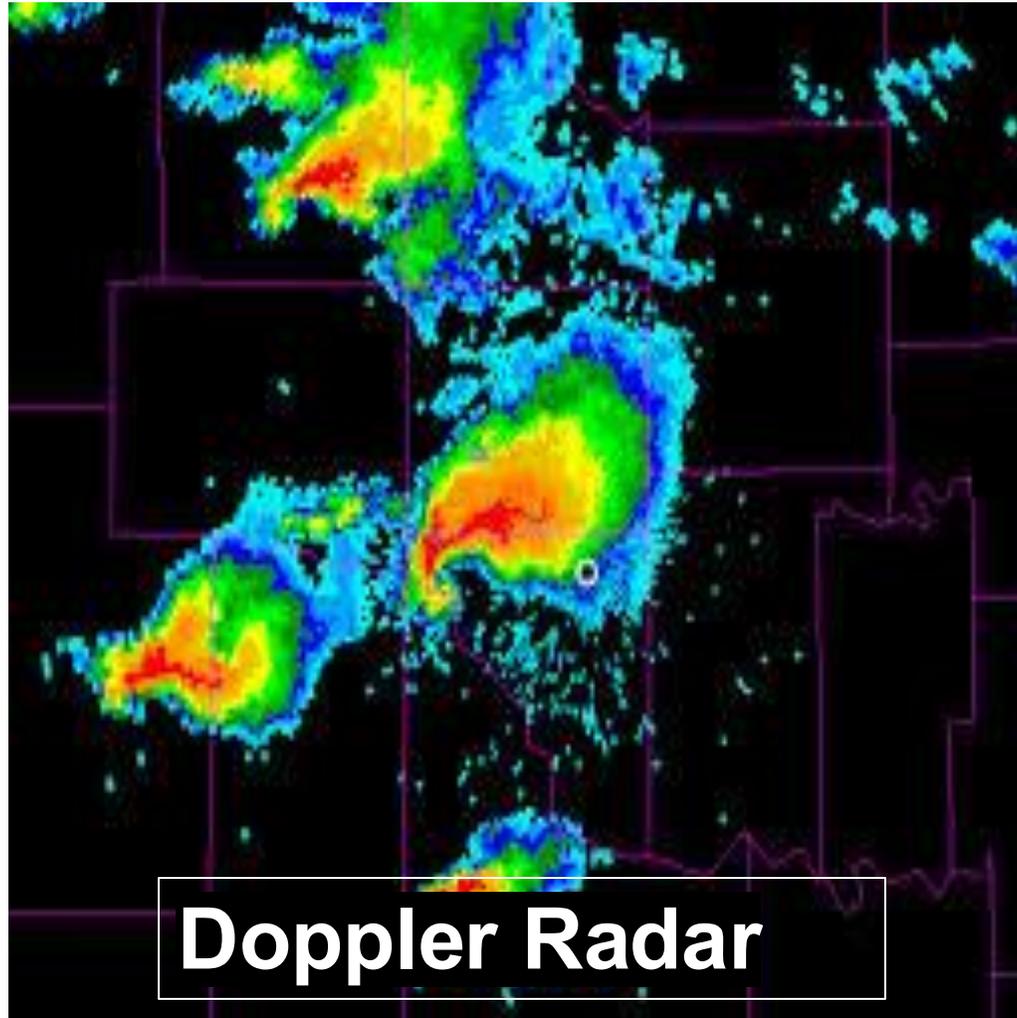
**Hurricane Katrina, 2005**  
Carribean, Atlantic Ocean,  
United States

In the **Southern Hemisphere**, it flows 



**Cyclone Debbie, 2017**  
Australia, New Zealand,  
Southern Pacific Ocean

# Detection of Tornadoes





---

## **Christian Doppler (1803-1853)**

- Austrian Physicist
- Doppler Effect (1842)

# How he discovered the Doppler Effect

- Curious about how motion affects waves
- Presented in Prague 1842: *Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels*
  - *On the Coloured Light of the Double Stars and Certain Other Stars of the Heavens*
- proposed that the colour of starlight could change depending on whether the star was moving towards or away from Earth
- 1845 First Experimental Support: Sound

## Ueber das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels.

(Gelesen bei der königl. Gesellschaft der Wissenschaften zu Prag, in der naturwissenschaftlichen Sectionssitzung vom 25. Mai 1842.)

### § 1.

Die Undulationstheorie des Lichtes, sowie sie *Euler* und *Huygens* allererst aufstellten und mit vielem Scharfsinne gegen die erklärtesten Gegner derselben vertheidigten, ist im Verlaufe ihrer weiteren Ausbildung bekanntlich auf Schwierigkeiten gestossen, welche spätere ausgezeichnete Gelehrte, wie *Young*, *Fresnel*, *Cauchy* u. A. dahin vermochten, von der ursprünglichen, wie es scheint nur allein naturgemässen und einfachen Voraussetzung sphärischer oder longitudinaler Aetherschwingungen abzugehen und sich zur Annahme blosser derartiger transversaler Schwingungen zu verstehen. Die glänzenden Erfolge dieser neuen Voraussetzung haben seitdem auch mehrere derjenigen Physiker, wenn auch nicht eben überzeugt doch vorläufig einigermassen beruhigt, welche sich von allem Anfange her nur höchst ungern und mit sichtlichem Widerstreben dieser neuen Ansicht über die Natur des Lichtes hingaben. Und so ist es denn gekommen, dass während diese Ansicht den feinsten analytischen Untersuchungen fortwährend zum Grunde gelegt wird, und zu mehr oder minder glücklichen Resultaten führet, man die Untersuchung und jegliche Discussion über die Zulässigkeit und innere Wahrscheinlichkeit dieser neuen Hypothese vor der Hand so gut wie fallen liess. Auf eine vollständige und erschöpfende Erklärung sämmtlicher bisher

# Doppler Effect

## Source VS Observer

The apparent change in a frequency of a wave cause by a relative motion between the source of the wave and the observer

$$f_o = \left( \frac{v \pm v_o}{v \mp v_s} \right) f_s$$

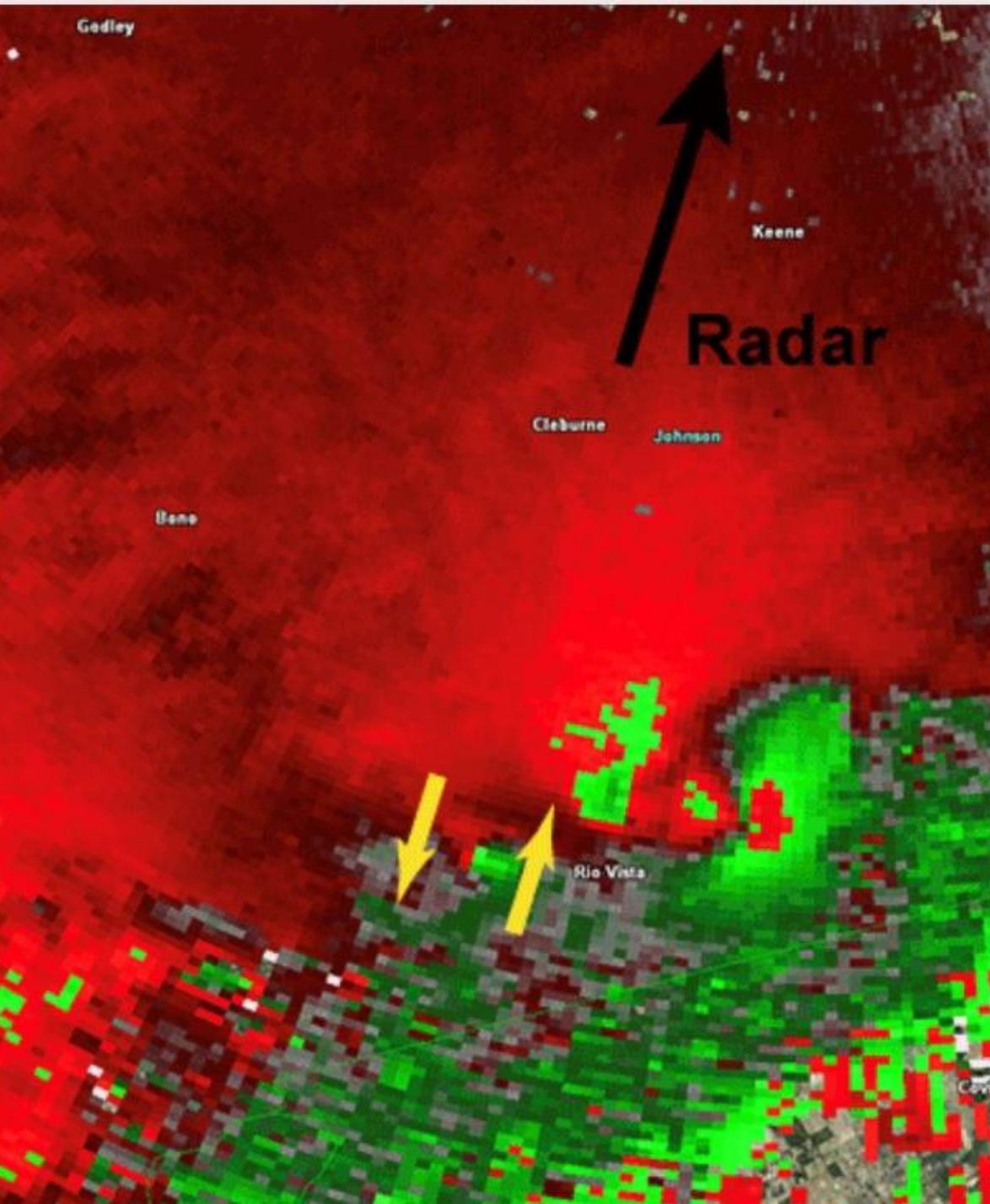
$f_o$  = The observer's frequency of sound

$v$  = Sound waves' speed

$v_o$  = The velocity of the observer

$v_s$  = Velocity of the source

$f_s$  = Sound waves' actual frequency



## How the Doppler Radar Detects Tornadoes

- Image of the doppler radar
- Red means the wind/precipitate is moving away from radar
- Green means wind/ precipitate is moving towards radar

---

# Sources

1. Brain, M., Lamb, R., & Simón, Y. (2023, September 11). What causes tornadoes? How tornadoes work. HowStuffWorks. <https://science.howstuffworks.com/nature/climate-weather/storms/tornado.htm>
2. Doppler effect explained. (n.d.). <https://byjus.com/physics/doppler-effect/>
3. Gerkema, T., & Gostiaux, L. (2012). A Brief History of the Coriolis Force. *Europhysics News*. <https://www.europhysicsnews.org/articles/ePN/pdf/2012/02/ePN2012432p14.pdf>
4. Harris, W. (2024, September 5). *How the Doppler Effect Works*. HowStuffWorks. <https://science.howstuffworks.com/science-vs-myth/everyday-myths/doppler-effect.htm>
5. LifeSecure. (2024). The physics behind tornadoes. In LifeSecure. <https://8941652.fs1.hubspotusercontent-na1.net/hubfs/8941652/Scientific%20paper-%20Tornado.pdf>
6. Microsoft PowerPoint - Lecture.19.tornado.2019w.pptx. (n.d.). In <https://www.ess.uci.edu/~yu/class/ess124/Lecture.19.tornado.all.pdf>  
<https://www.ess.uci.edu/~yu/class/ess124/Lecture.19.tornado.all.pdf>
7. National Oceanic and Atmospheric Administration. (2023, September 27). *How radar works*. <https://www.noaa.gov/jetstream/doppler/how-radar-works>
8. The physics of tornadoes and Hurricanes. Physics of Tornadoes and Hurricanes. (n.d.). [https://phys420.phas.ubc.ca/p420\\_04/sean/](https://phys420.phas.ubc.ca/p420_04/sean/)
9. Webb, P. (n.d.). *8.4 Hurricanes*. Introduction to Oceanography. <https://rwu.pressbooks.pub/webboceanography/chapter/8-4-hurricanes/>

---

# Literature Review

- Google Document link:

<https://docs.google.com/document/d/1kbphwnQ1XTDcxcT3KJ3qS6D1jX6kGETwAiVwZSY0su0/edit?usp=sharing>

**Thank You!**