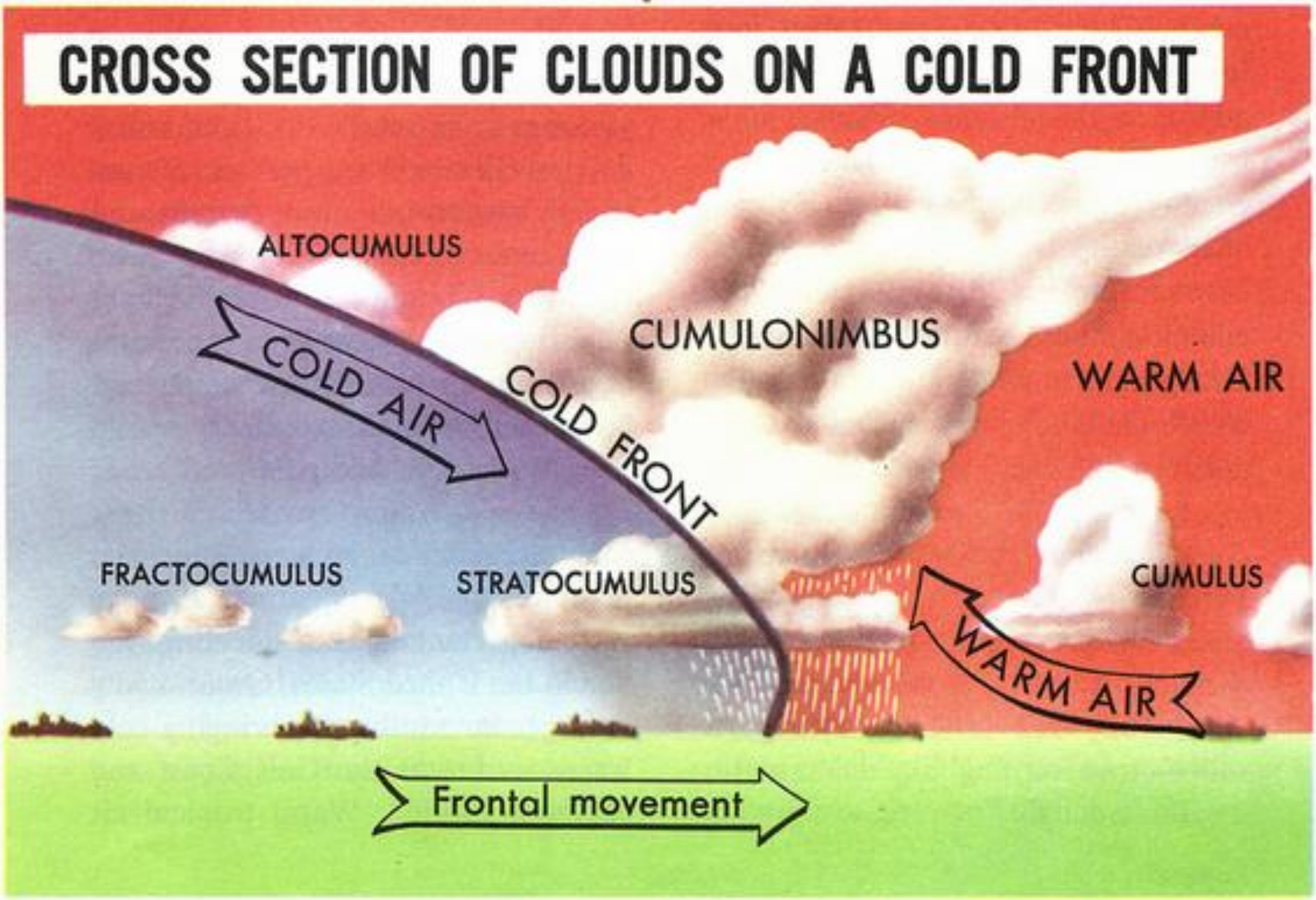
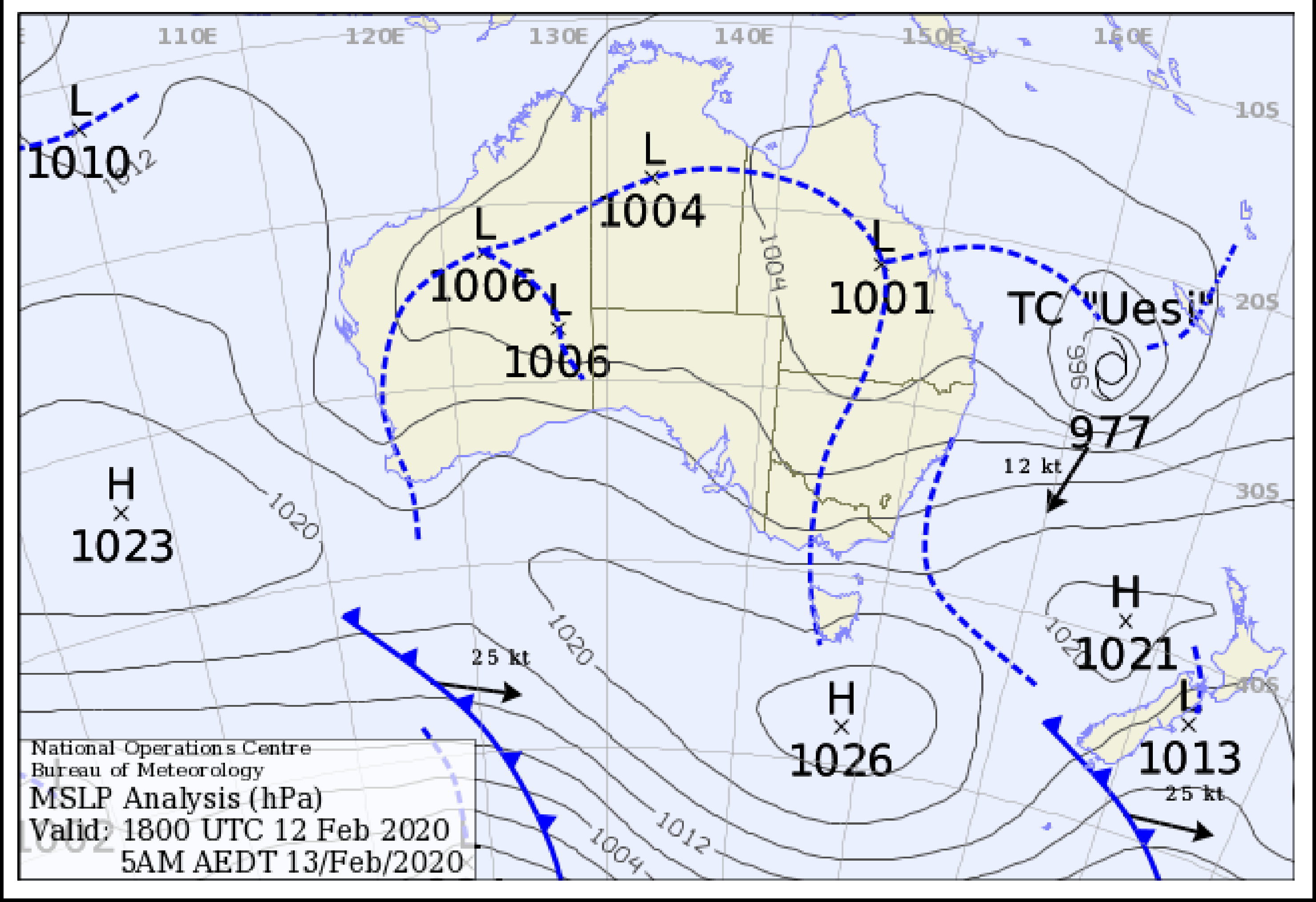
Understanding weather and the weather forecast

Week 17 Weather Radar

Terry Hart


CROSS SECTION OF CLOUDS ON A COLD FRONT
ALTOCUMULUS
CUMULONIMBUS
WARM AIR
COLD AIR
COLD FRONT
FRACTOCUMULUS
STRATOCUMULUS
CUMULUS
WARM AIR
Frontal movement

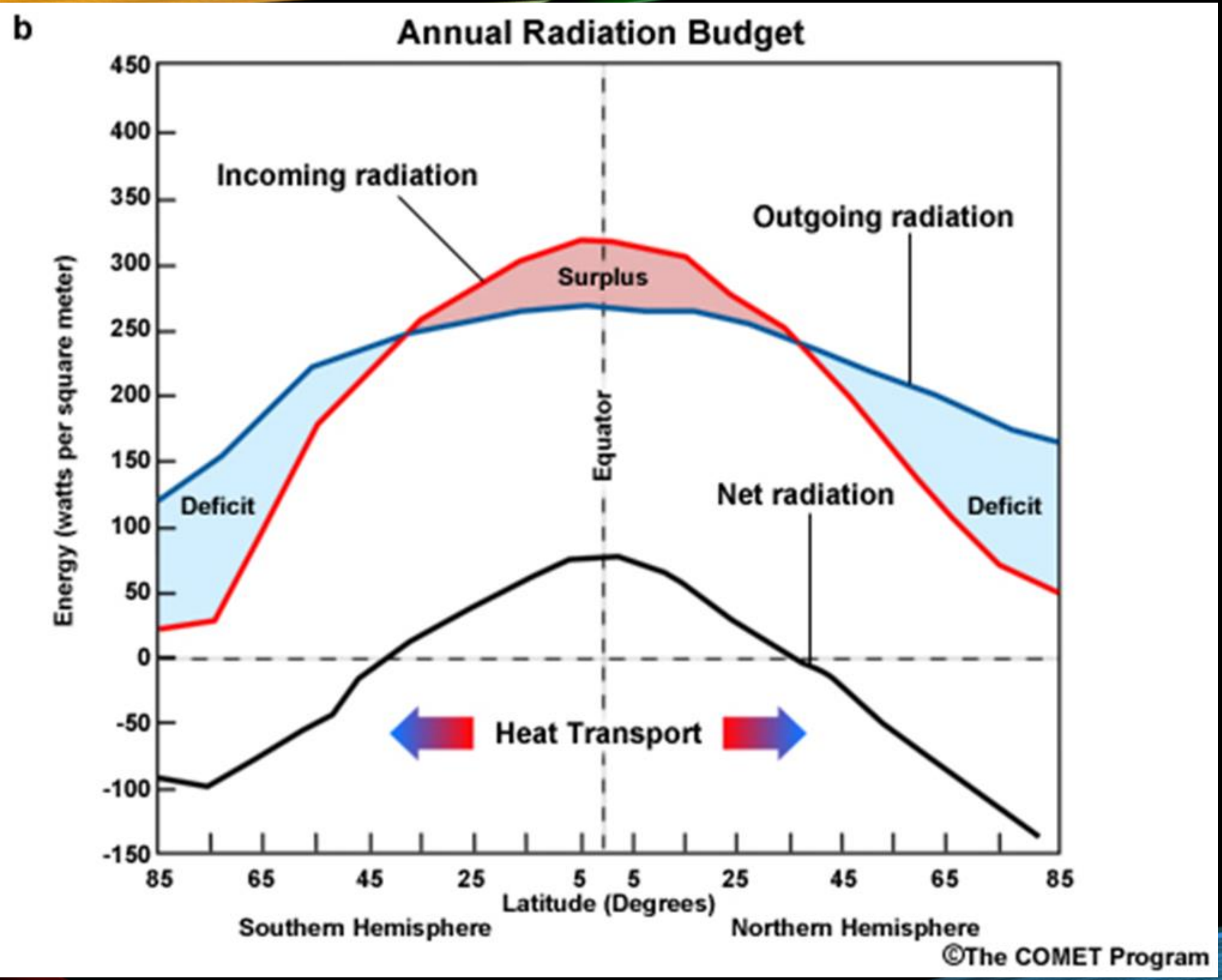
This weather map shows lines of equal Mean Sea Level Pressure (MSLP). Marked on it are fronts and also dotted lines indicating a line of relatively low pressure (called a **trough**)



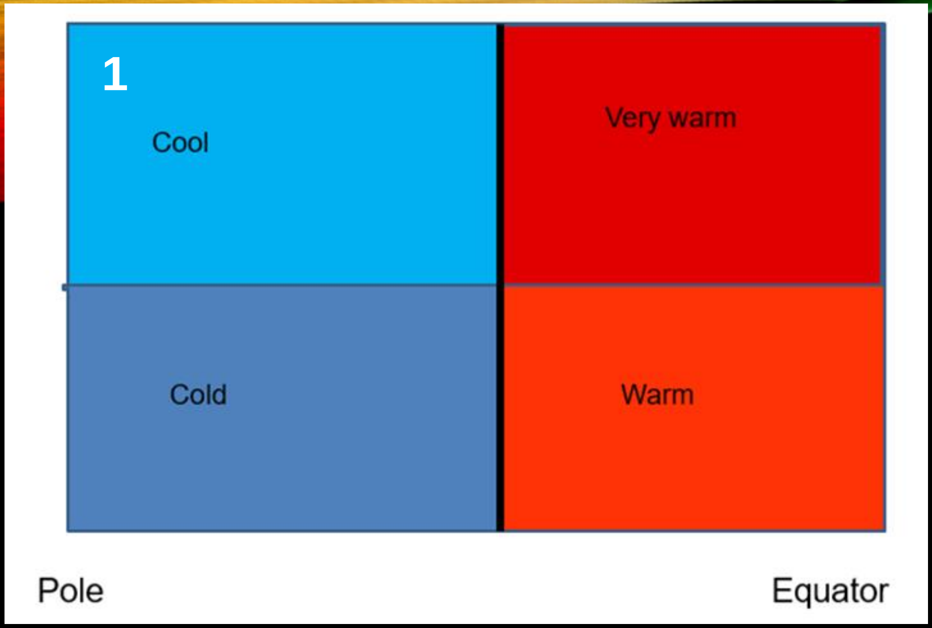
Fronts are tied up with the development of lows

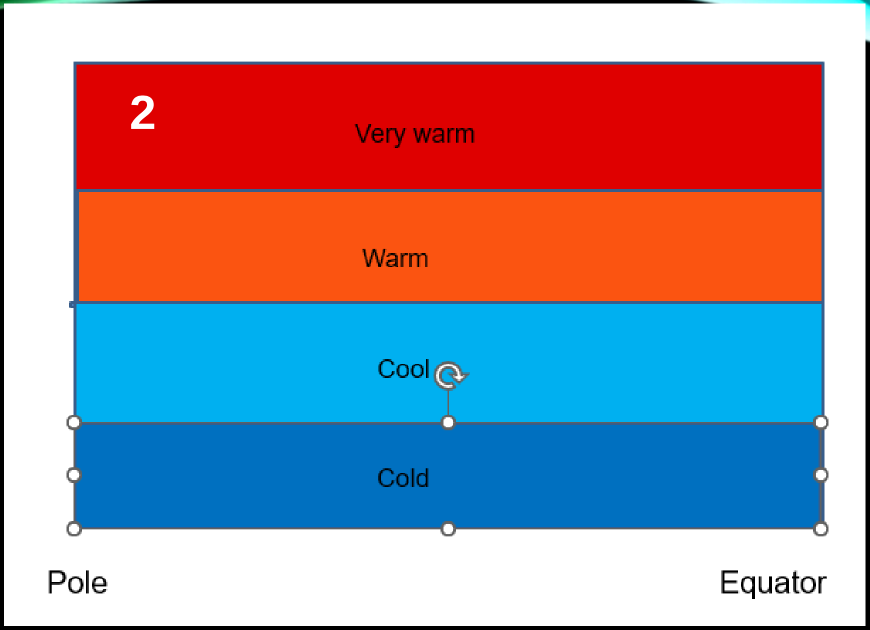
Where there is some underlying contrast in temperature (usually north to south) fronts can be formed or at least re-activated by the development of a low (called **cyclogenesis**)

Very rapid development of a low (explosive cyclogenesis) is sometimes called a **“weather bomb”**
https://youtu.be/lXgWTzHKn-w



Lows and fronts are important! They play a big role in carrying heat from tropical to polar areas.



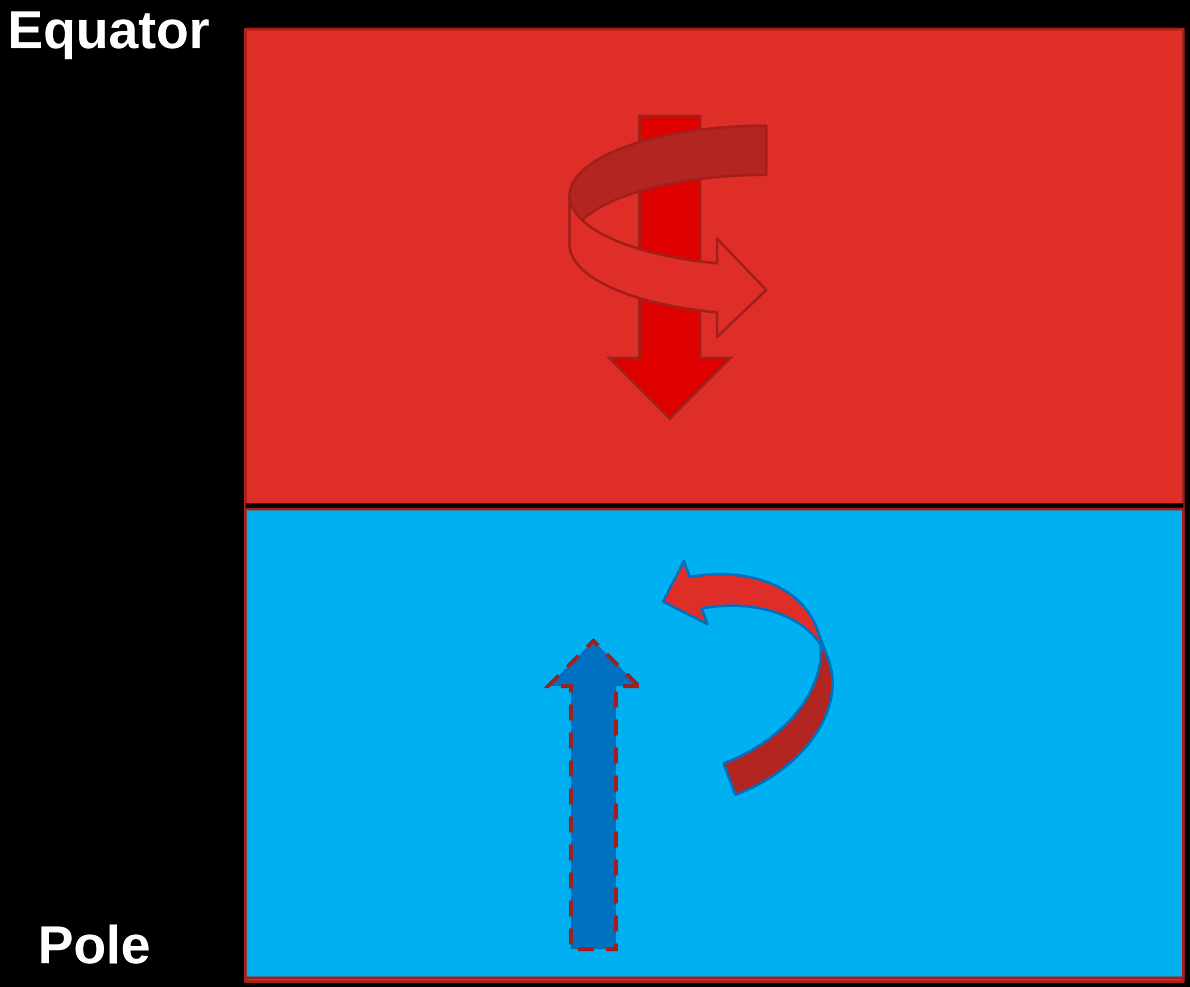


A simplified picture of the atmosphere (1), imagining a partition between the tropics and the higher latitudes.
If the barrier is removed (2), the fluids **move.** **I**n the end, the air is **stable** – the less dense air is at the top and the coldest (densest) at the bottom.

- Some of the cold air has moved downwards and toward the Equator
- Some of the warm air has moved upwards and toward the Pole.

In technical terms**,** some of the **potential energy** in the partitioned fluid (1) gets translated into motion (**kinetic energy**).

Looking from the top, there is an important complication on our rotating earth – the Coriolis Effect.

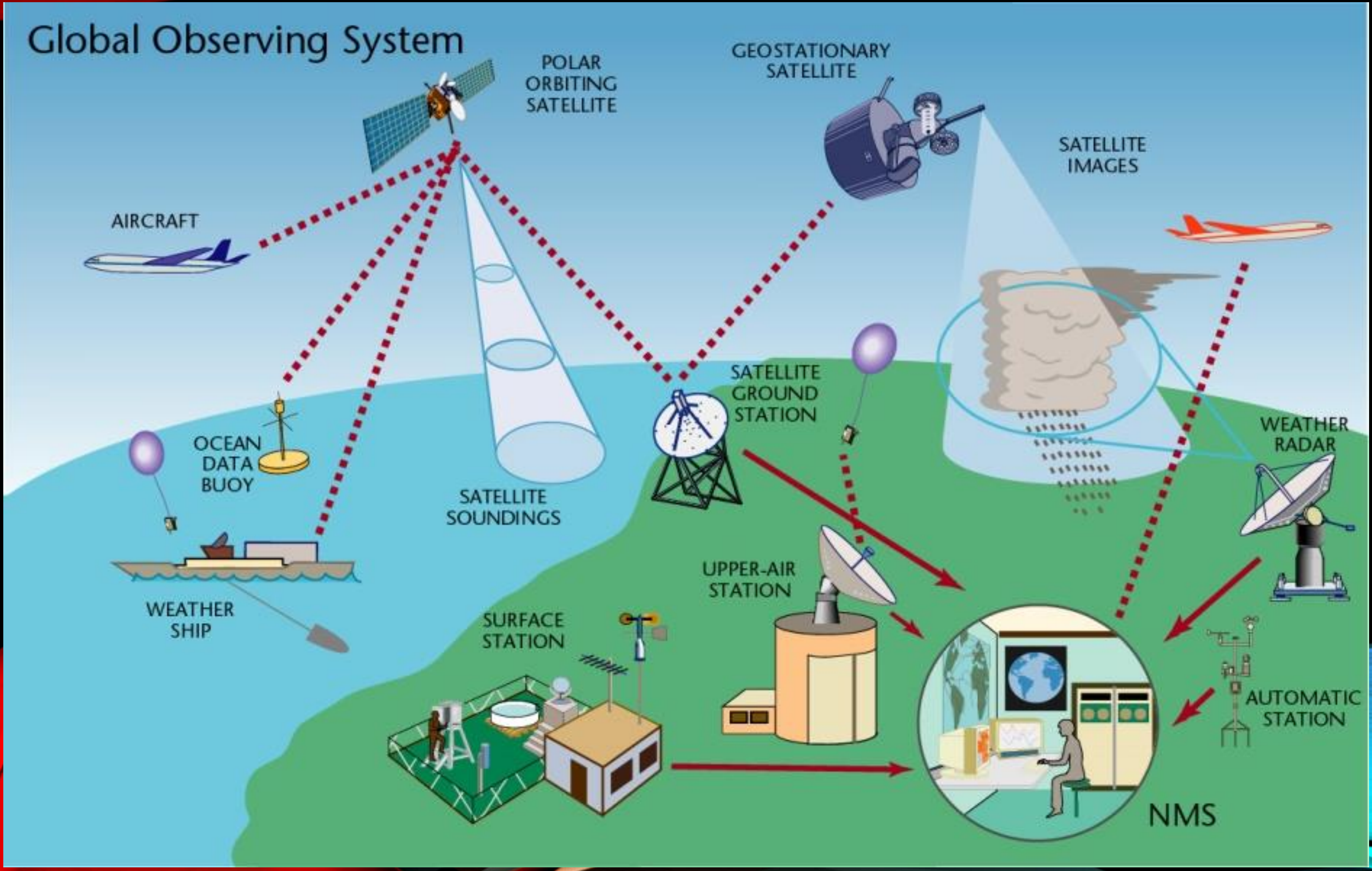


As the warm air moves south it is deflected to the east

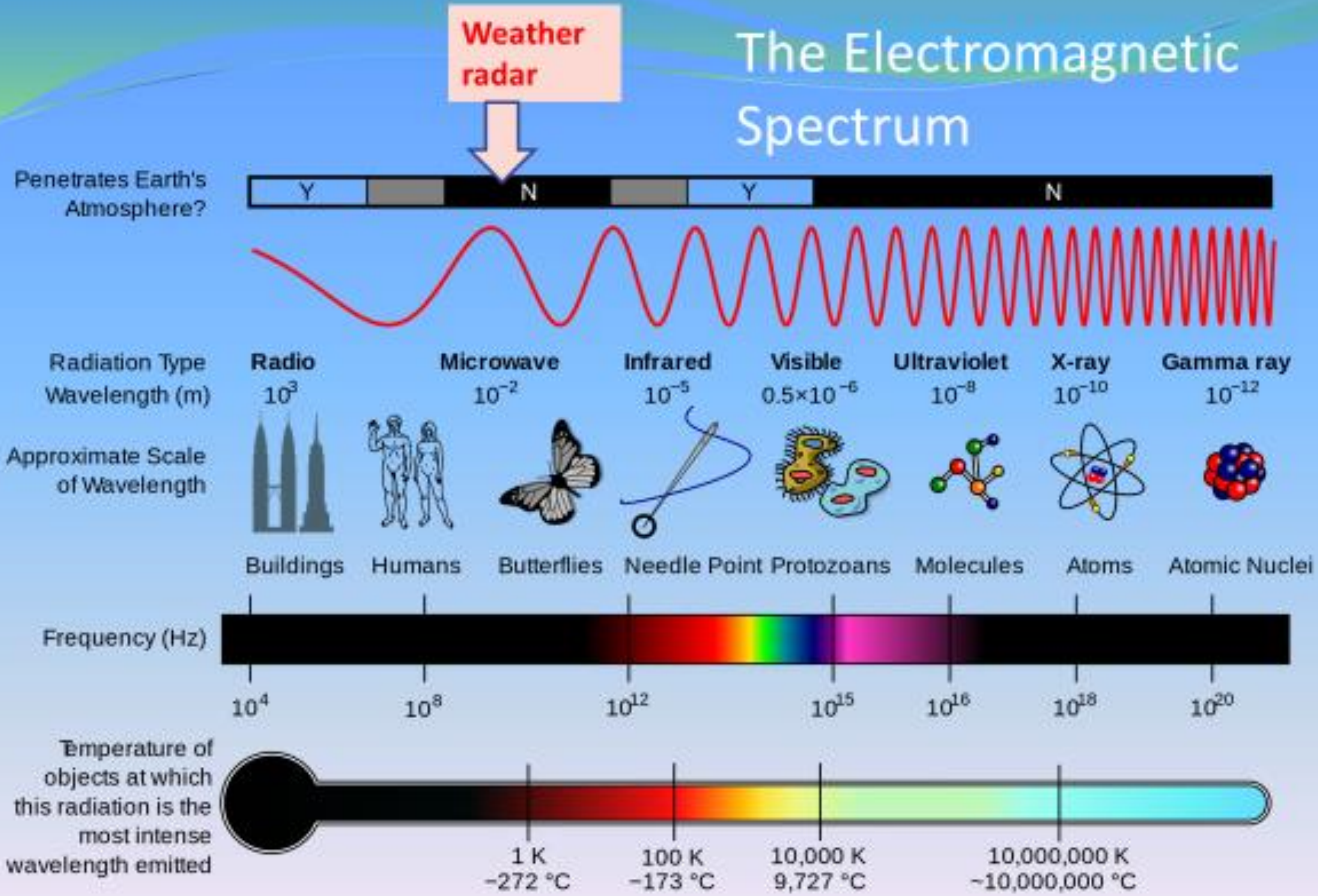
As the cold air moves north it is deflected to the west

So we end up with a clockwise circulation, a low.

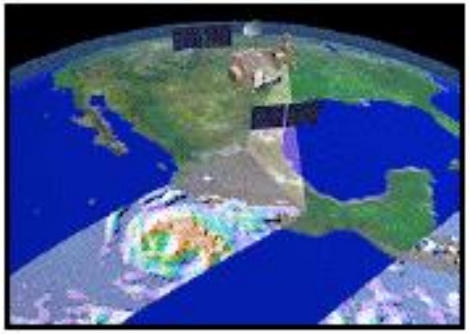
Observing the atmosphere uses many different types of systems and measurements



The Electromagnetic Spectrum



RADAR: Radio Detection And Ranging


- Developed during World War II as a method to detect the presence of ships and aircraft (*the military considered weather targets as noise*)

- Since WW II, there have been many advances in radar technology (e.g., Doppler techniques) and it's used on land, sea, and in space for both research and operational needs



During World War II, radar operators discovered that weather was causing echoes on their screens, masking potential enemy targets.

After the war, surplus radars were used to detect precipitation. Since then, weather radar has evolved on its own and is now used by national weather services.

In US, David Atlas at first working for the Air Force and later for MIT, developed the first operational weather radars.

Images can be used to make short term forecasts of future positions and intensities of rain, hail, and other weather phenomena.

Now specialized software can take radar data to detect and provide alerts on severe weather or used in computer weather models to improve analyses and forecasts.

Ask BOM – How does a Weather Radar work?

https://www.youtube.com/watch?v=NZ7rNeQck2A

https://www.facebook.com/groups/1008662393031389/permalink/1130425990855028/

Anatomy of a Weather Radar

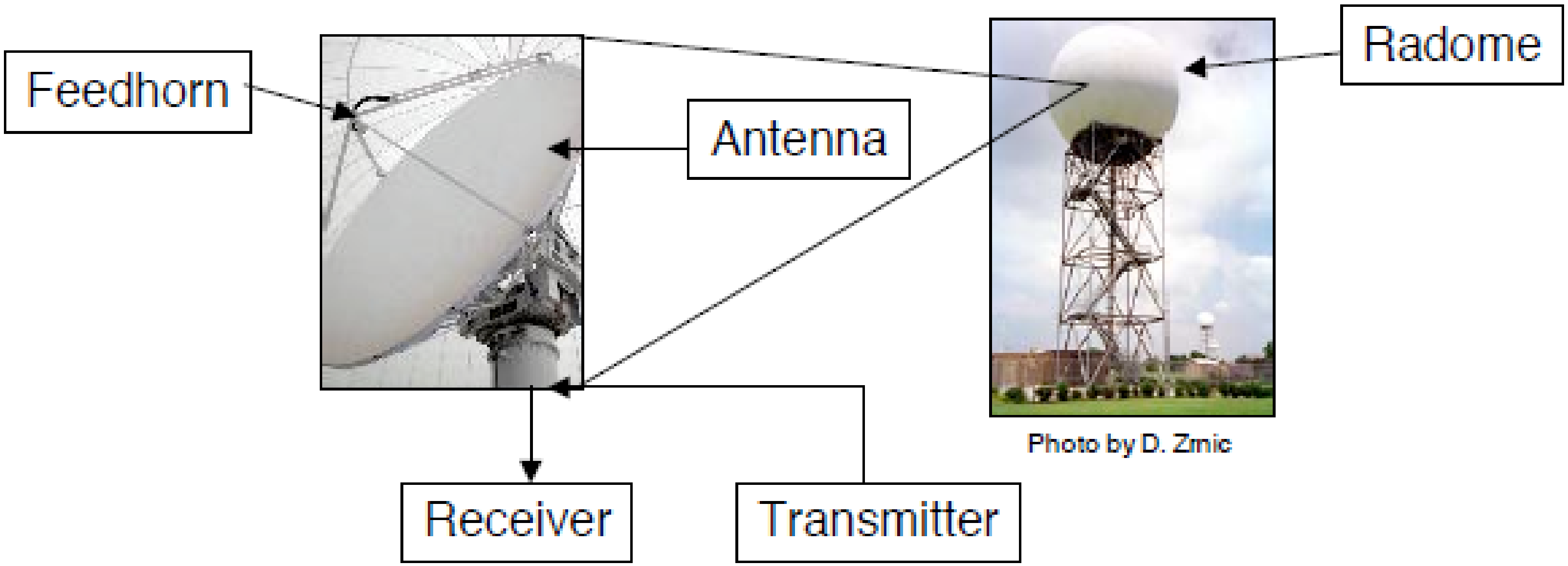


Photo by D. Zrnic

- **Transmitter** - generates the microwave signal of the correct phase and amplitude. For a weather radar, the wavelength of the signal is ~ 10cm
- **Antenna** - the main purpose of the antenna (also called the "dish") is to focus the transmitted power into a small beam and also to listen and collect the returned signal
- **Feedhorn** - directs the signal from the transmitter onto the antenna (also directs the return signal from the antenna to the receiver)
- **Receiver** - detects the signal returned from a target
- **Radome** - protects the antenna from high winds

How Does the Radar Sense a Target in the Atmosphere?

- Radars operate by sending out energy from a source and "listening" to the amount that is reflected (scattered) from targets
- Targets can be trees, cloud, bumblebees or anything else the radar pulse intercepts
- Weather radars utilize frequency of ~ 3000 MHz (10 cm wavelength) - radio waves
- The radar transmits short pulses of these radio waves at rate of ~ 1000 pulses/s
- Each pulse is very short, lasting only about 1/1,000,000 s

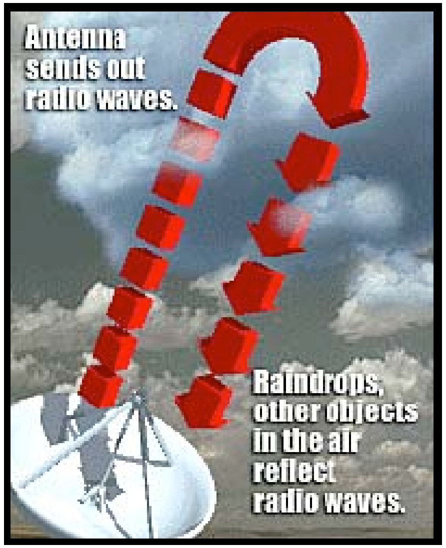
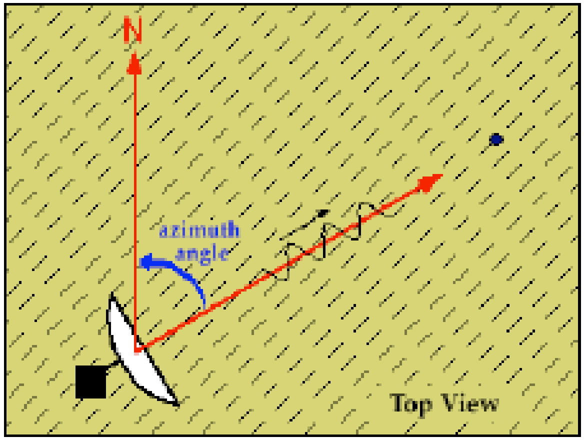


Image from The USA TODAY Weather Book *by Jack Williams*

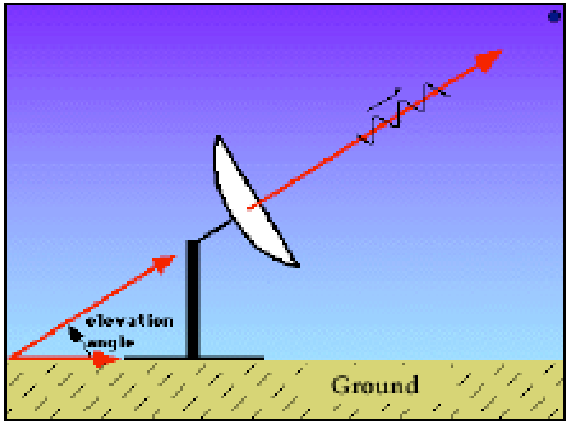
The return signal received by the radar is related to the diameter of the particles in our target echo: the bigger the particles the bigger the amount of return signal.

Weather Radar Scanning

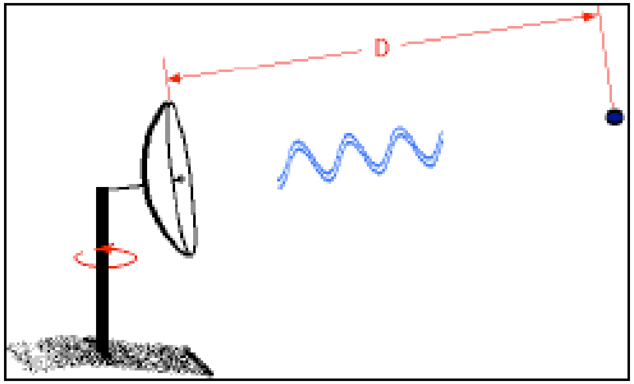
For a radar to find a target of interest (e.g., a cloud), 3 pieces of information are needed:



- *Azimuth angle (direction relative to north)*



- *Elevation angle (angle above the ground)*



- *Distance to the target of interest*

Images on this page made available from the University of Illinois WW2010 Project

The microwave radiation (which travels at the speed of light) has to travel from the transmitter to the weather target and back again, a distance which could be several hundred kilometers.

Horizontal distance from station to target - from the time delay between the transmitted and the return signal

The radar makes a scan around 360 degrees at a low elevation angle, then tilts up a few degrees and makes another scan. The process is repeated until the full volume has been scanned.

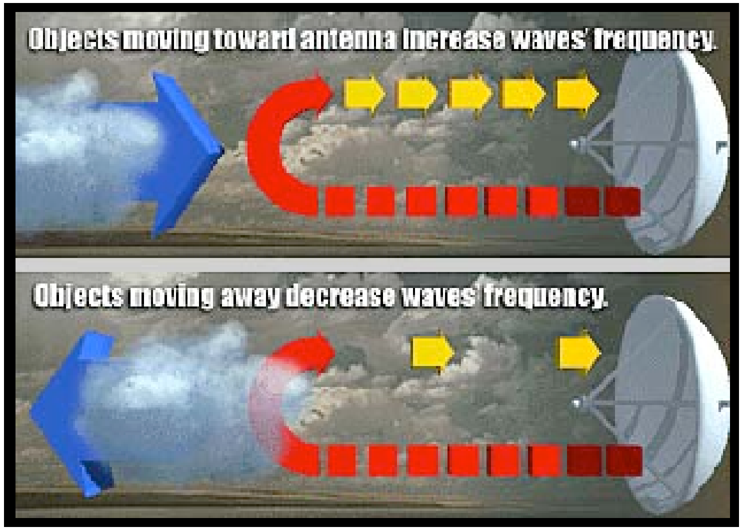
That can take at least 5 minutes. That is why the Bureau radar images are 6 minutes apart for the main radars, and 10 minutes for others.

The standard radar image shows the **reflectivity**.
An estimate can be made of the **rainfall rate**.

Doppler Radar

Measuring Air Motion with Radar

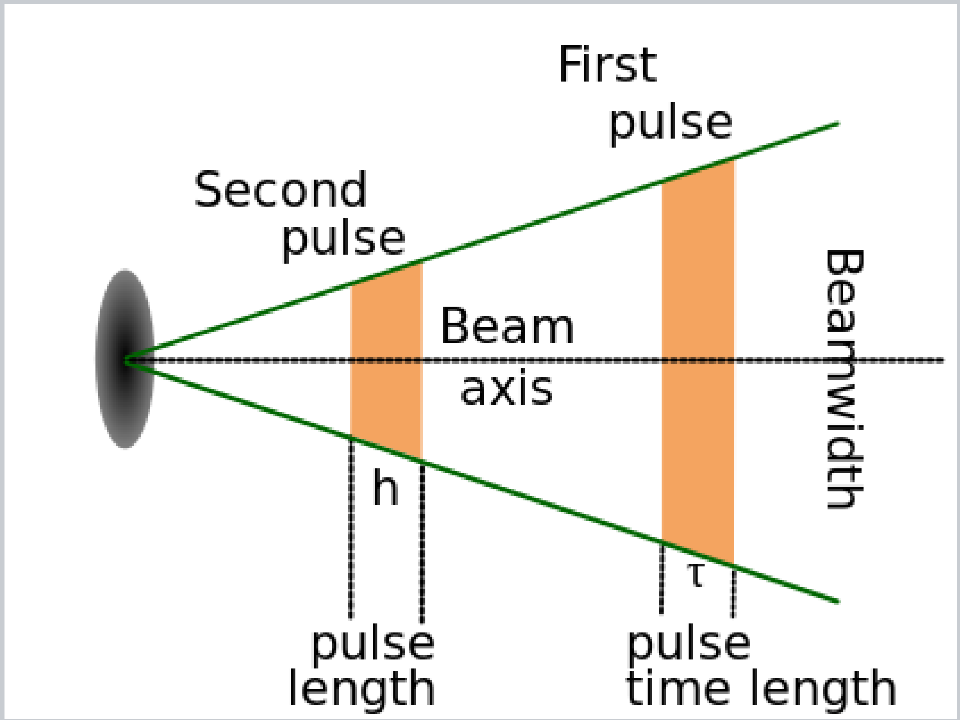
In addition to measuring the amount of signal returned from targets, *NEXRAD* radar has the added capability of being able to measure a frequency shift that is introduced into the reflected signal by the motion of the precipitation particles. This frequency shift is then used to determine wind speed (*we assume that the particles are instantaneously moved around by the wind*).



Images from The USA TODAY Weather Book *by Jack Williams*

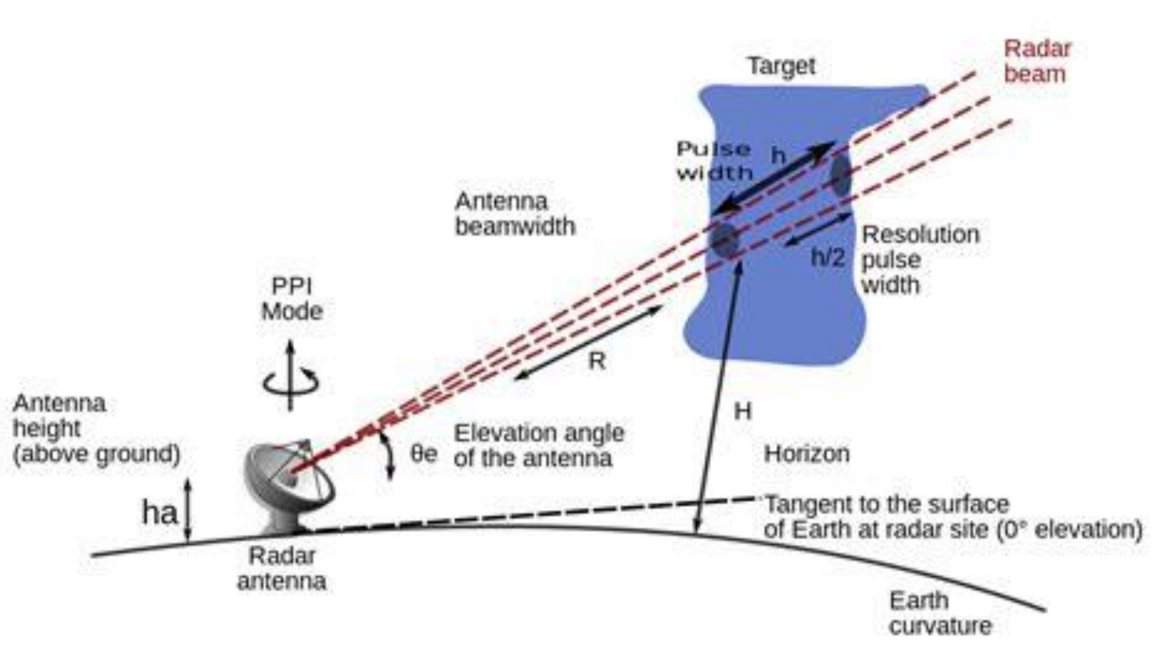
- The amount of "shift" can be determined by comparing the frequency of the transmit pulse with the frequency of the reflected pulse
- Particles moving toward the radar are shifted to higher frequency
- Particles moving away from the radar are shifted to lower frequency

Some problems with weather radar



A radar beam spreads out as it moves away from the radar station, covering an increasingly large volume.

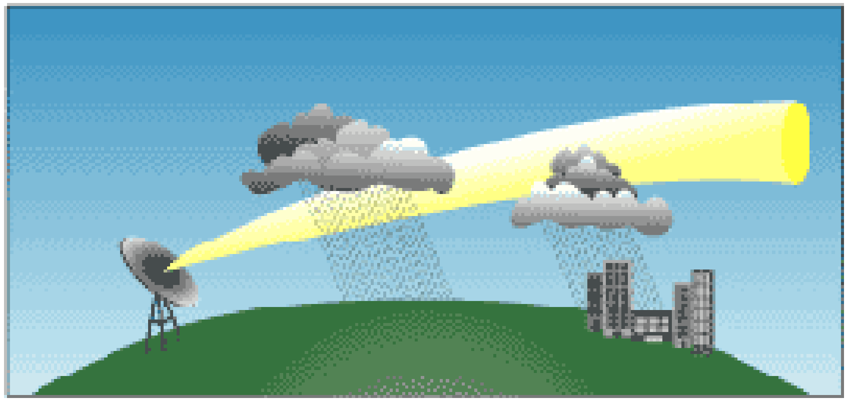
As you move further away from the radar, the radar beam broadens. So, the proportion of the beam that is filled with rain lessens and reduces the echo intensity.



The radar beam gets further from the ground with distance because of the Earth's curvature.

So, lower parts of the rain can be missed.

For example, a horizontal radar beam detects raindrops at about 1 kilometre above the ground when it is 100 kilometres away from the radar. Rain that is 200 kilometres away from the radar will be detected at a height of 3 km.



The effects of the curvature of the earth on weather radar.

There is some refraction of the beam towards the earth.

Non-weather targets

Some things can be misinterpreted as rain or snow by radars:

- Insects
- Birds
- Solid obstacles such as mountains, buildings, and aircraft
- Wind farms
- Dust and smoke
- Ground and sea clutter.

Some can be removed by various processing techniques. E.g. the pattern of “permanent” echoes can be removed, although it does affect the radar image in those areas.

The rotating blades of **wind farms** can return the radar beam to the radar if they are in its path. Since the blades are moving, the echoes can be mistaken for real precipitation.

"THIS is not rain, not ground clutter," NBC meteorologist Lauryn Ricketts tweeted on Monday. "So likely CICADAS being picked up by the radar beam."

Lauryn Ricketts
@laurynricketts

THIS is not rain, not ground clutter (the radar beam picking up objects close the radar site --which is in Loudoun County).... the Hydrometeor Classification algorithm identifies this as biological in nature..so likely CICADAS being picked up by the radar beam...

1:49 AM · Jun 8, 2021

7.3K 294 Share this Tweet

Kyle Pallozzi, a Virginia-based meteorologist for the National Weather Service, told Insider that Ricketts' suspicion was "100%" true.

Lady bugs on radar

To explore some past cases:
http://www.theweatherchaser.com/radar-loop/

Some examples:

- Thunderstorms in Melbourne : 22 March 2019 02-11 UTC
- Tropical Cyclone Debbie: Bowen or Mackay radars: 27 March – 1 April 2017
- Rain in Sydney 1 – 4 July 2022
- Black Saturday, Melbourne: 7 February 2009 02-15 UTC
  - both the standard images and the Doppler view.
- Hail in Brisbane: 27 November 2014 03-09 UTC