DEPARTMENT OF GEOGRAPHY

The Atmosphere

GEOG0005

Dr Eloise Marais

- Associate Professor in Physical Geography
- Atmospheric chemistry modelling
- Air quality and human health
- Human influence on the atmosphere

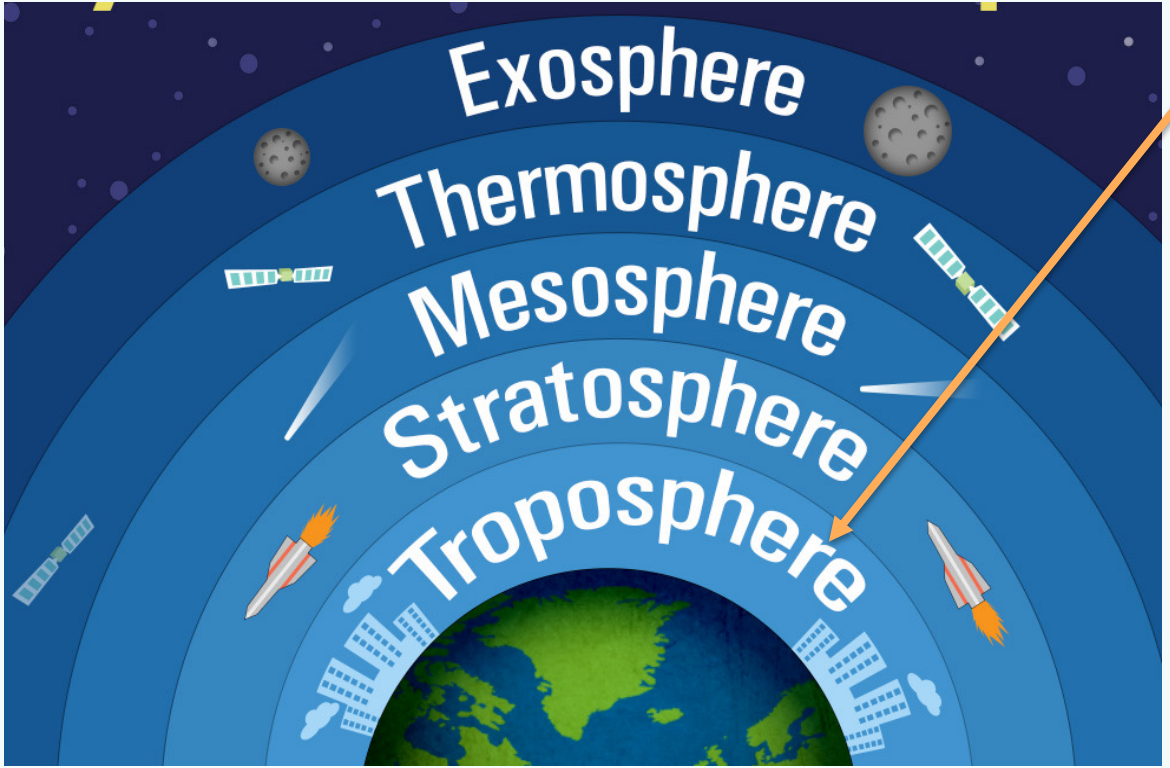
Website of the research group I lead:
https://maraisresearchgroup.co.uk/

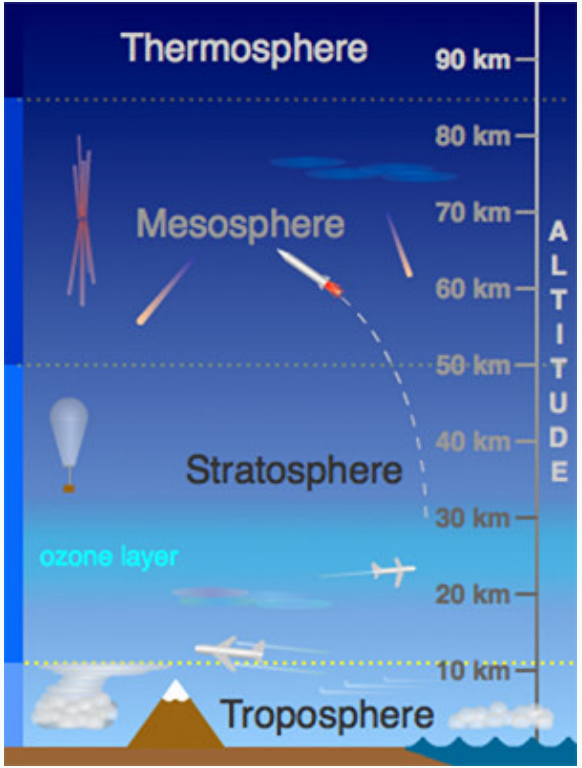
The Atmosphere

- Lecture 1: Weather
- Lecture 2: Climate
- Lecture 3: Climate Change

Atmospheric Layers

Troposphere:
Where Earth's weather occurs





DEPARTMENT OF GEOGRAPHY

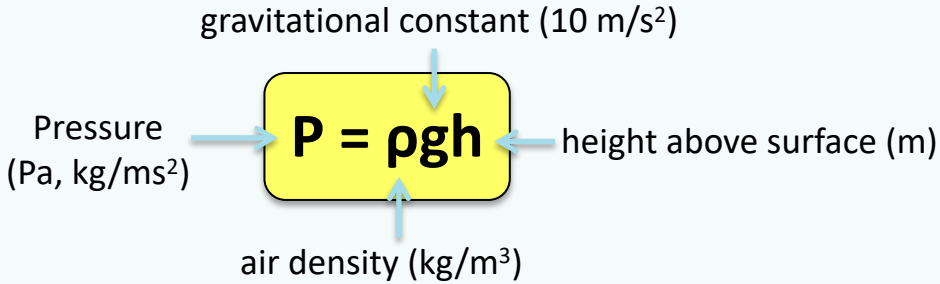
Weather

Earth GEOG0005

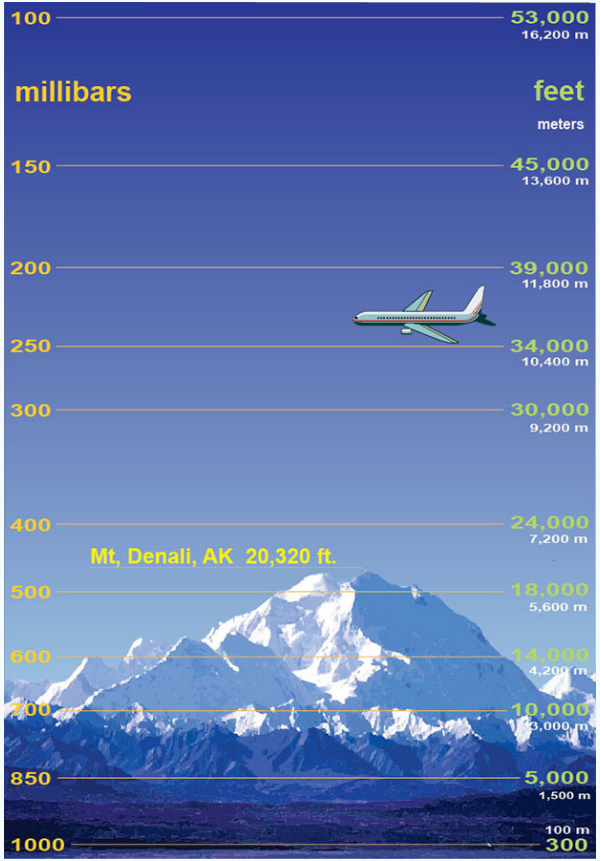
Weather

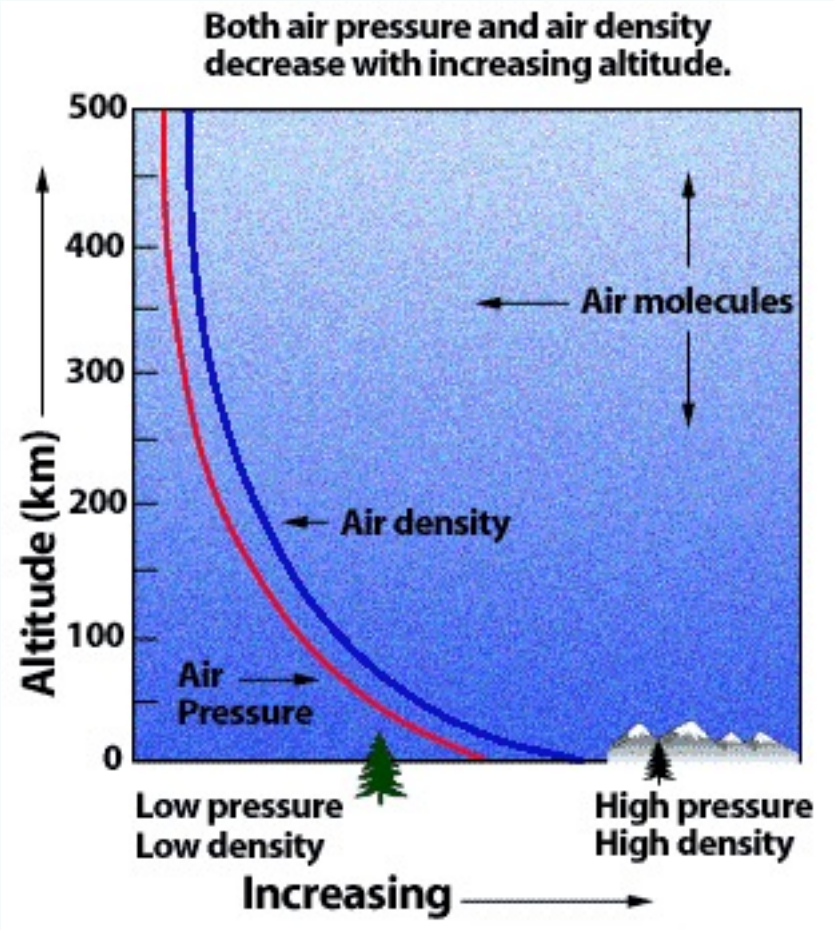
- Weather is:
  - the instantaneous state of the atmosphere
  - We will focus on Earth's weather (there is also space weather)
  - what we experience on a daily basis
- Type of weather depends on location
  - latitude, altitude, terrain, water bodies
- Climate is long-term average weather

Atmospheric Pressure

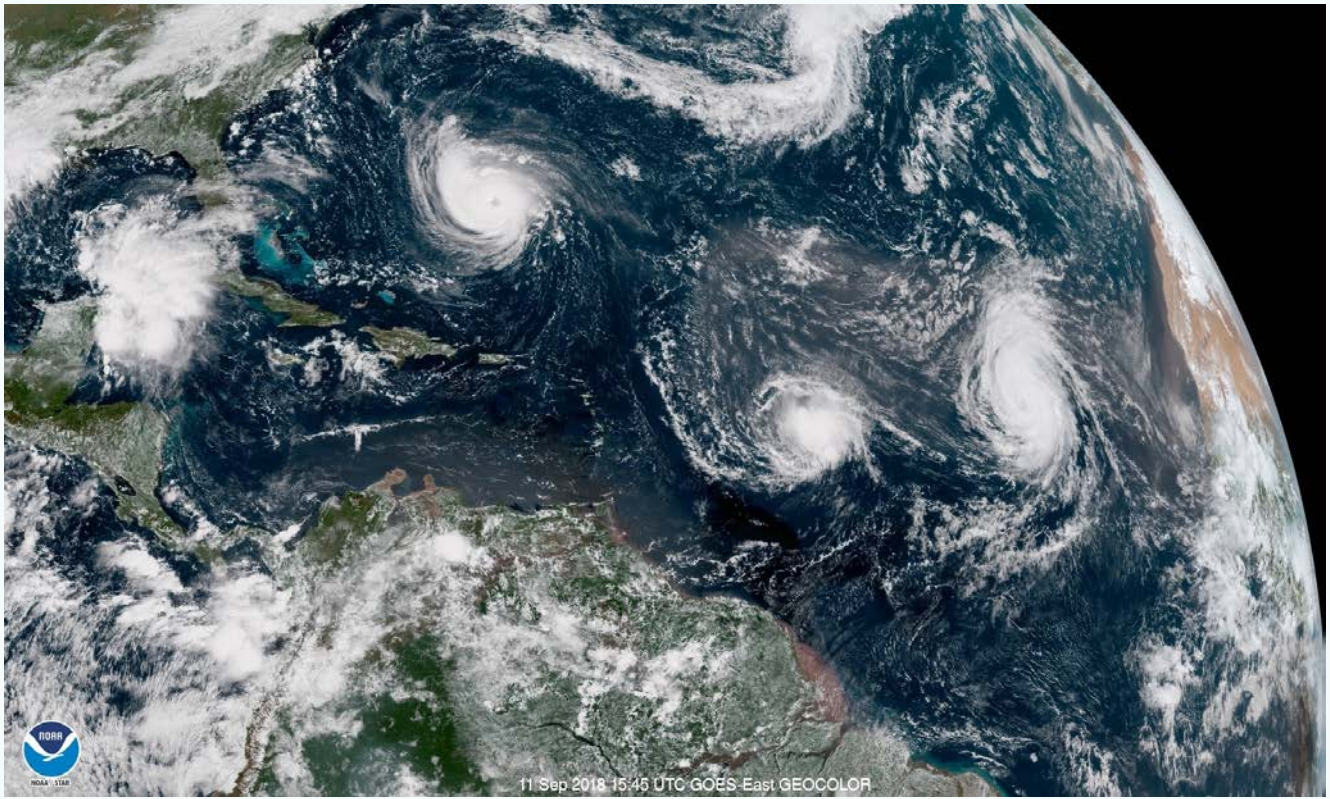


- Measured in millibars (mb)
  - 1 mb = 100 Pa = 1 hPa
  - Average sea level pressure is 1013 mb
- Air density decreases with altitude
  - Most air molecules held tightly to surface (gravity)
  - Pressure decreases with altitude


100
53,000
16,200 m
millibars
feet
meters
150
45,000
13,600 m
200
39,000
11,800 m
250
34,000
10,400 m
300
30,000
9,200 m
400
24,000
7,200 m
Mt, Denali, AK 20,320 ft.
500
18,000
5,600 m
600
14,000
4,200 m
700
10,000
3,000 m
850
5,000
1,500 m
100 m
1000
300


Both air pressure and air density decrease with increasing altitude.
Altitude (km)
500
400
300
200
100
0
Air molecules
Air density
Air Pressure
Low pressure
Low density
High pressure
High density
Increasing

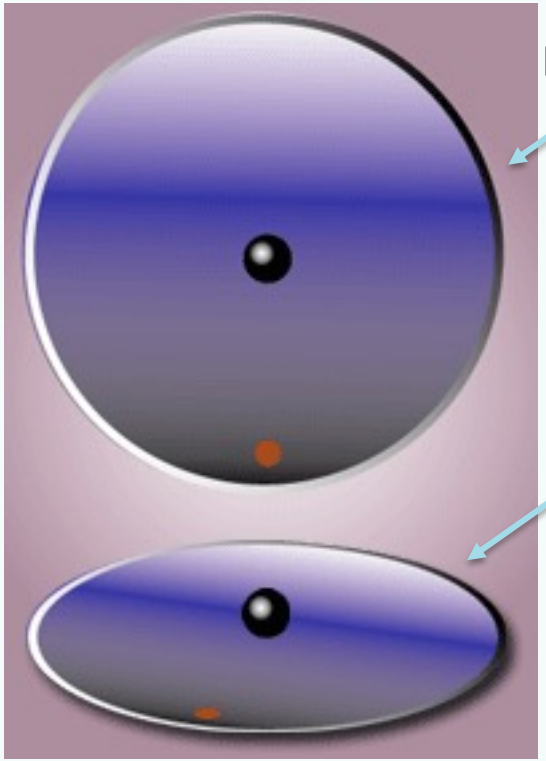
Earth’s weather patterns



Reference Frames

- A reference frame is what the observer is looking at (in this case, the Earth)
- But the reference frame (Earth) is moving too. This is termed a non-inertial reference frame
- Objects in the Earth's reference frame experience virtual forces related to the movement of the reference frame

Inertial vs Non-Inertial Reference Frame



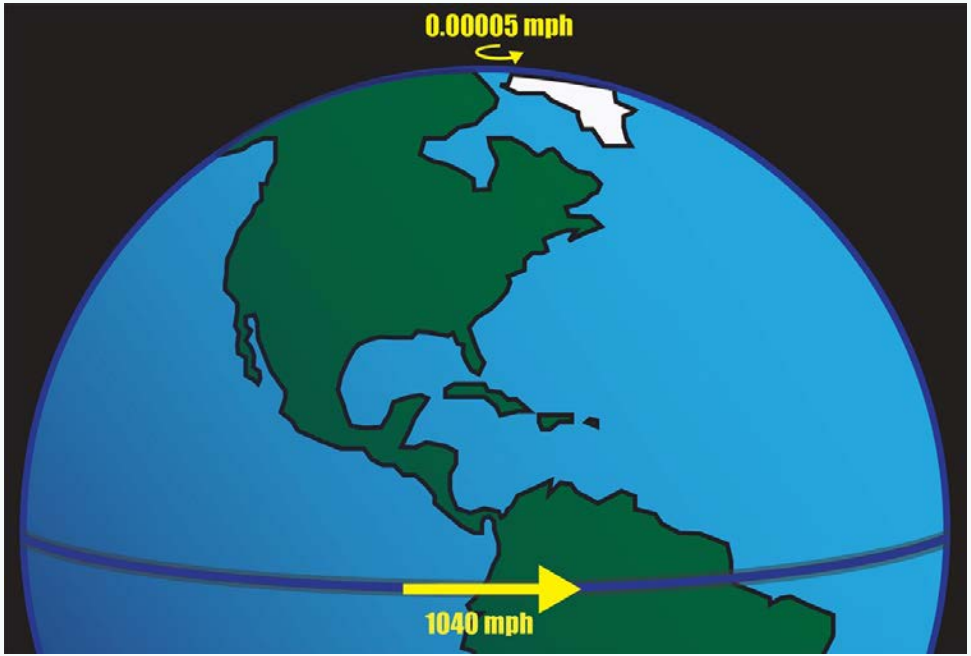
Disk: Earth
Black ball: air parcel

Inertial (static) frame of reference:
Black ball appears to move in a straight line

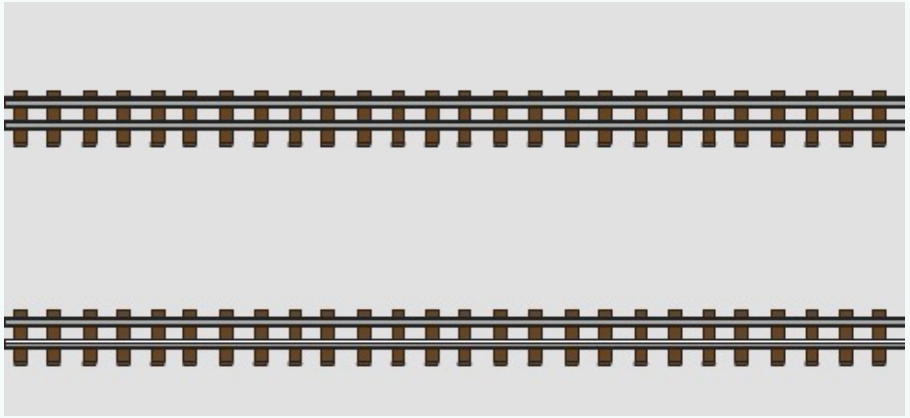
Non-inertial (moving) reference frame (observer): Black ball follows a curved path

This is due to the **Coriolis Force/Effect (a fictitious force)**

Equator moving faster than poles



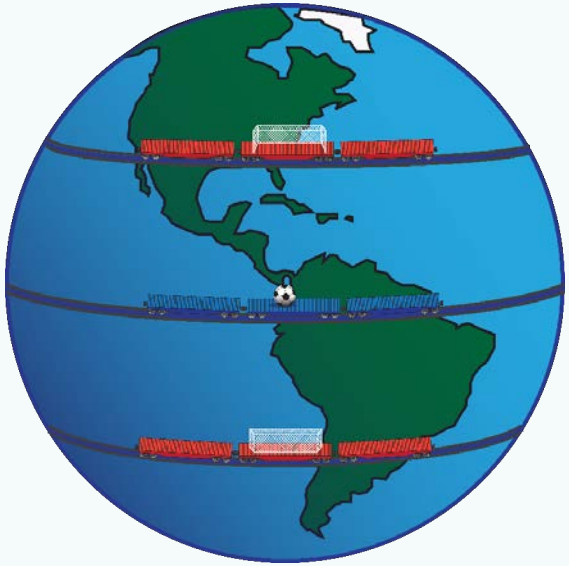
Polar train

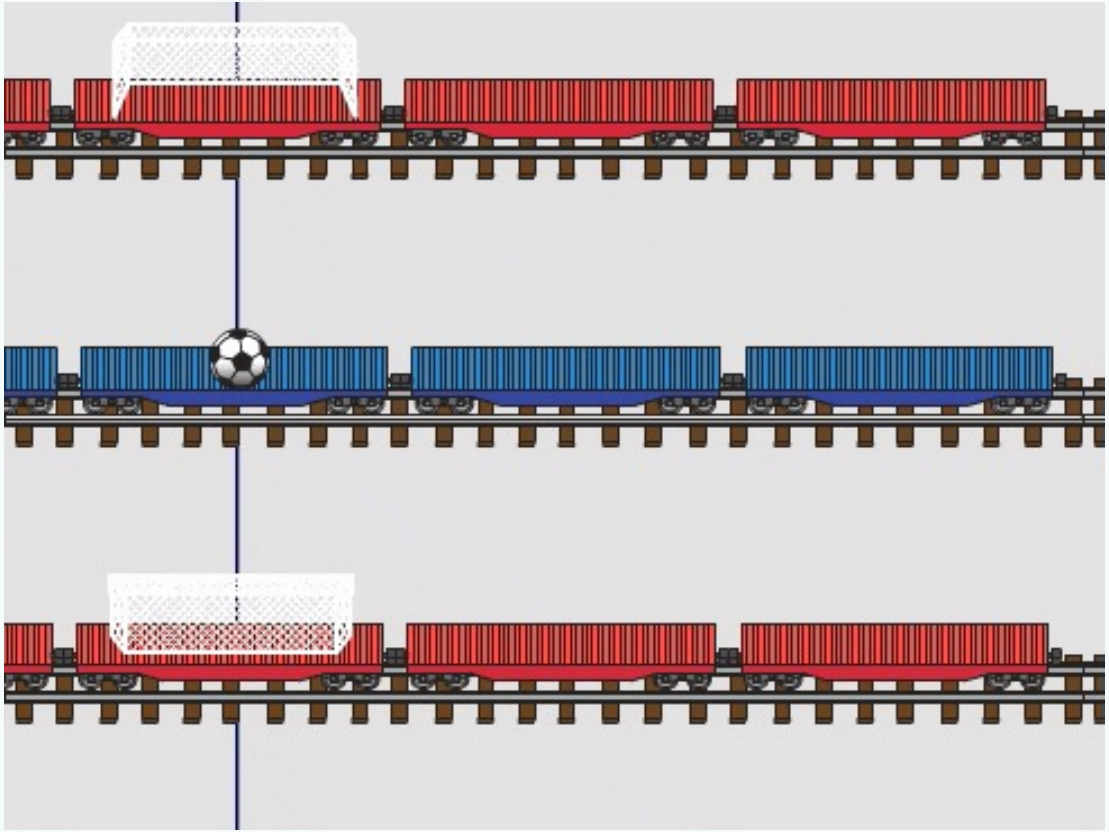


Equator train

Ball (air mass) is going in the direction and speed of the Equator train

URL of train and ball example: https://scijinks.gov/coriolis/

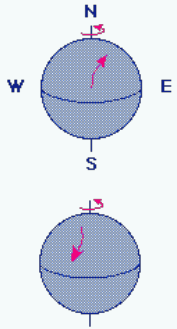




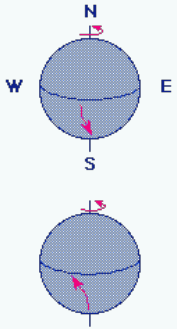
Deflection of air parcel

To the **right** in the **northern hemisphere**

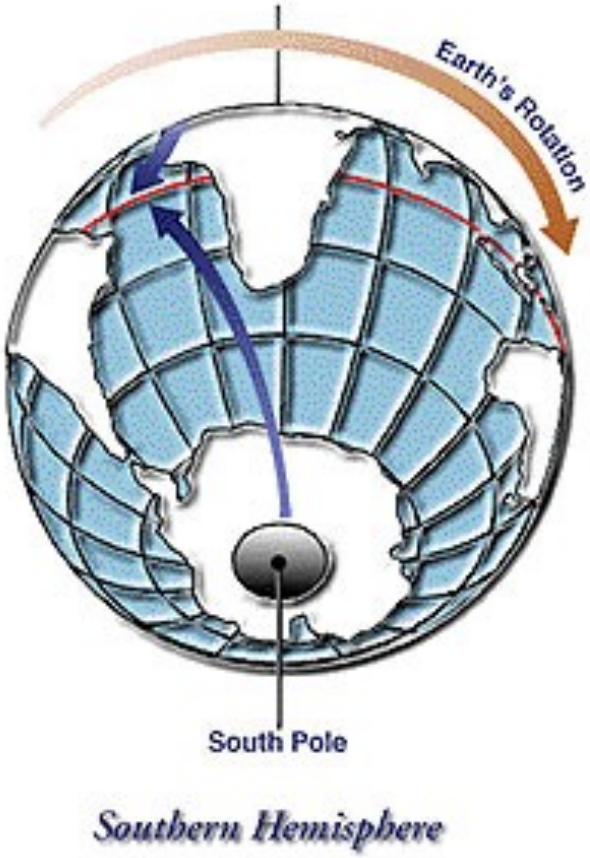
To the **left** in the **southern hemisphere**



Deflection to the right in the Northern Hemisphere



Deflection to the left in the Southern Hemisphere



Coriolis Effect

- The Coriolis effect is a quasi-force or fictitious force exerted on a body when it moves in a rotating reference frame:

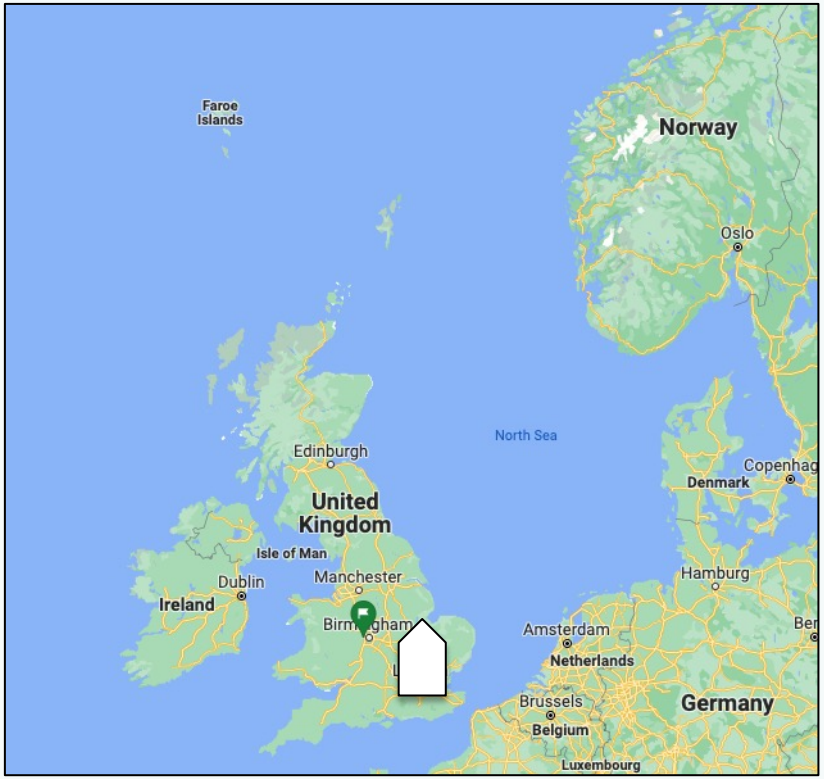
$$F = ma = -2m(\Omega \times \nu)$$

- The force F is at 90^o angle with respect to the object.
- m = mass of object (kg); Ω = Earth's rotation speed (radians/s); ν = air parcel velocity (m/s)

Coriolis Force Multiple Choice

If you throw a paper plane in a straight line due north from London on a calm day, the plane will:

A. Continue due north
B. Deflect to the east
C. Deflect to the west
D. Deflect to the south



Coriolis Force Multiple Choice

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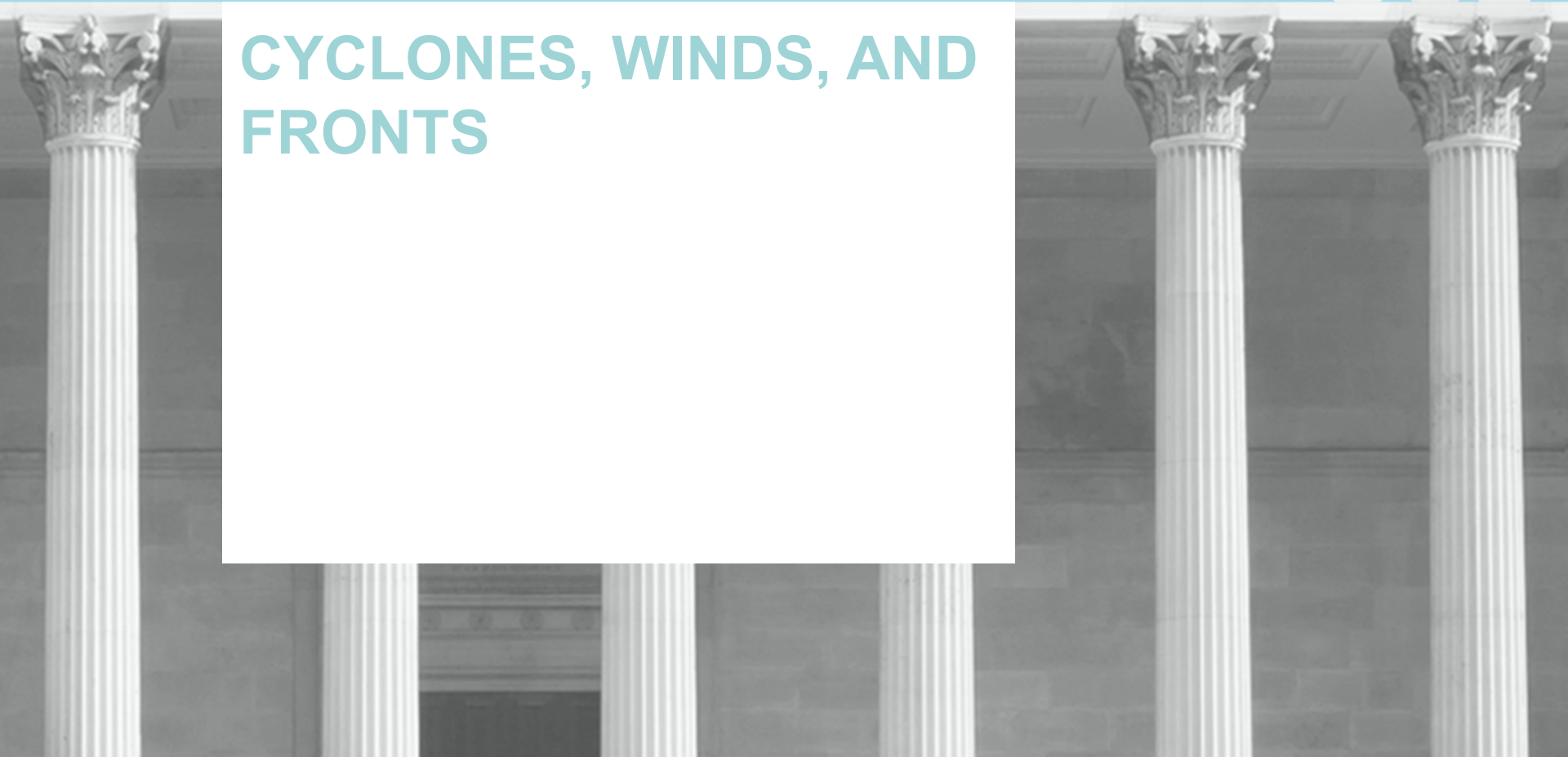
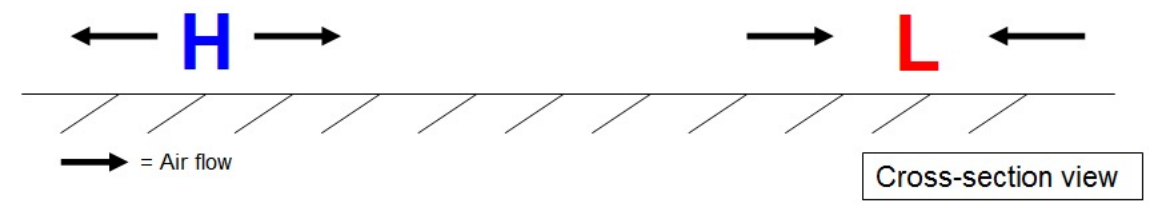
CYCLONES, WINDS, AND FRONTS



Air moves along the gradient from high to low pressure



And is deflected due to the Coriolis effect

Cyclones Multiple Choice

A storm around a low-pressure system spins _____ in the northern hemisphere and _____ in the southern hemisphere:

A. Clockwise, clockwise
B. Anti-clockwise, anti-clockwise
C. Clockwise, anti-clockwise
D. Anti-clockwise, clockwise

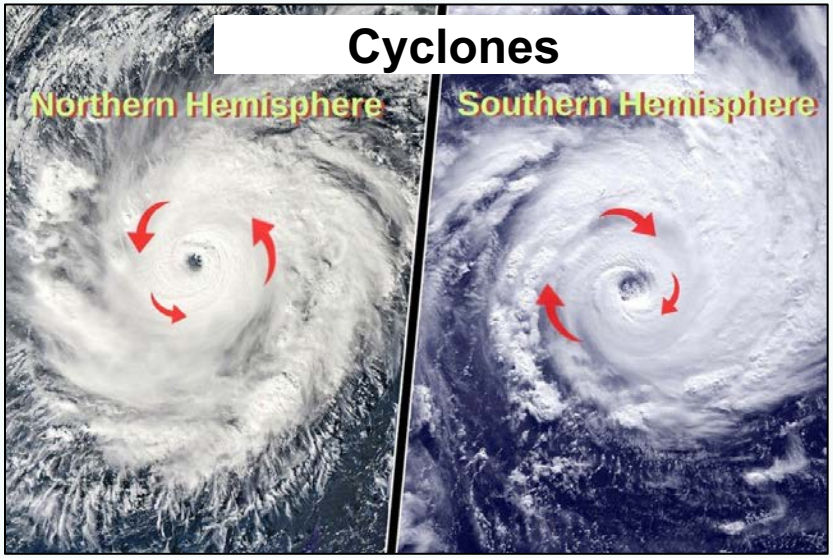
Cyclones Multiple Choice

A storm around a low-pressure system spins _____ in the northern hemisphere and _____ in the southern hemisphere:

A. Clockwise, clockwise
B. Anti-clockwise, anti-clockwise
C. Clockwise, anti-clockwise
D. Anti-clockwise, clockwise

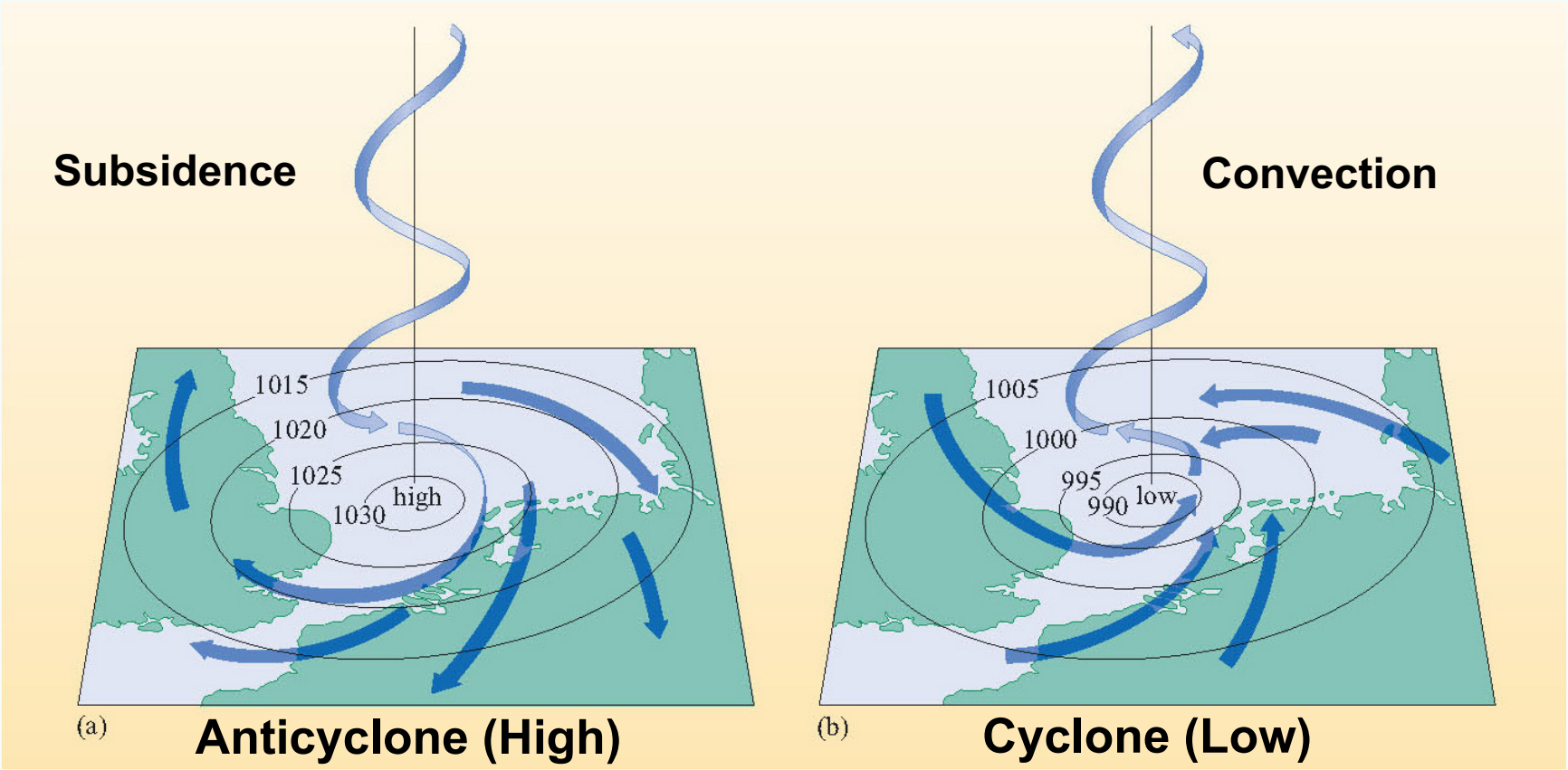
Cyclones

- Cyclone: air spins into low pressure
  - Anticlockwise in northern hemisphere
  - Clockwise in southern hemisphere
  - Also called depressions or “lows”



- Anticyclone: air spins outward from high to low pressure

Example high and low pressure systems over UK

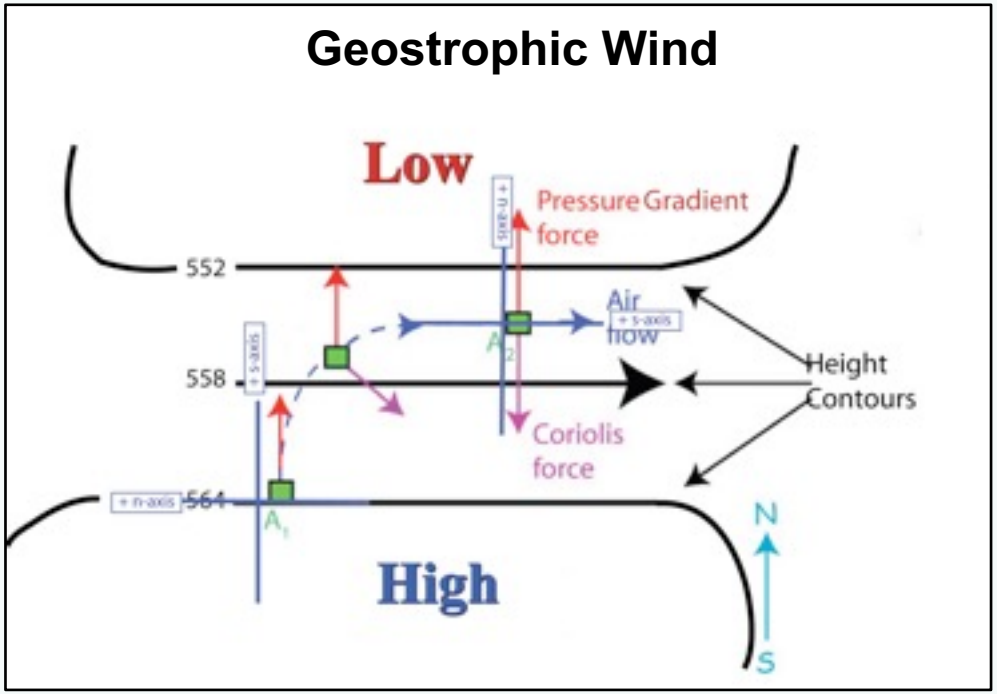


Surface Winds

Geostrophic wind is the theoretical wind due to balance between the Coriolis and pressure gradient forces

Ignores friction

Geostrophic wind flows parallel to isobars (lines of constant pressure)



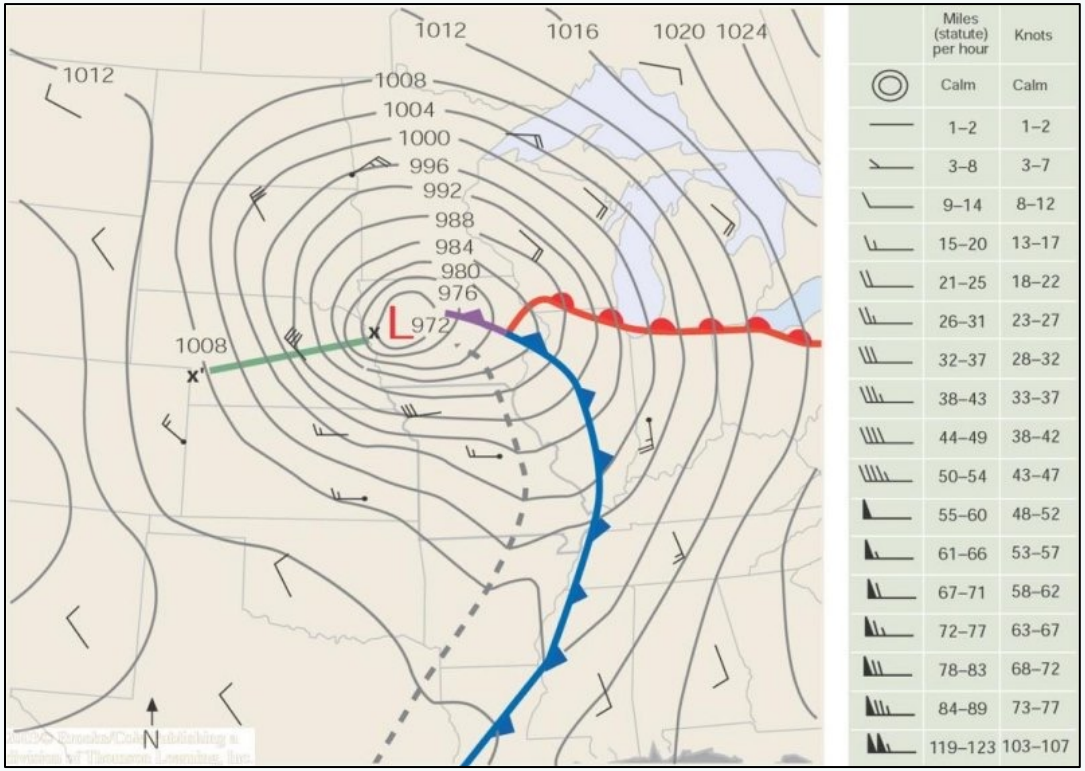
Surface Winds and Friction

Friction at Earth's surface disrupts geostrophic wind balance

Closer isobars → stronger pressure gradient → faster wind speed

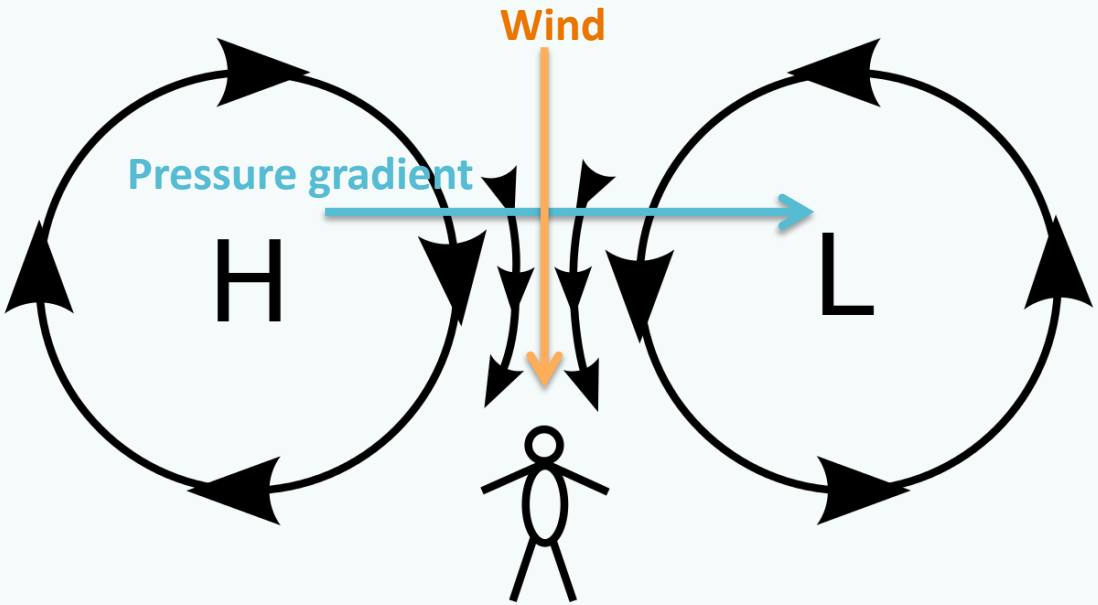
Wind "barbs"  indicate wind speed

1 knot is ~1.9 km/h



Buys-Ballot's Law

With your back to the wind, you can determine the location of high and low pressure



Due to the Coriolis effect, angle between the wind and pressure gradient is at 90^{o} (assumes frictionless atmosphere)

In the northern hemisphere: atmospheric pressure is low to the left and high to the right

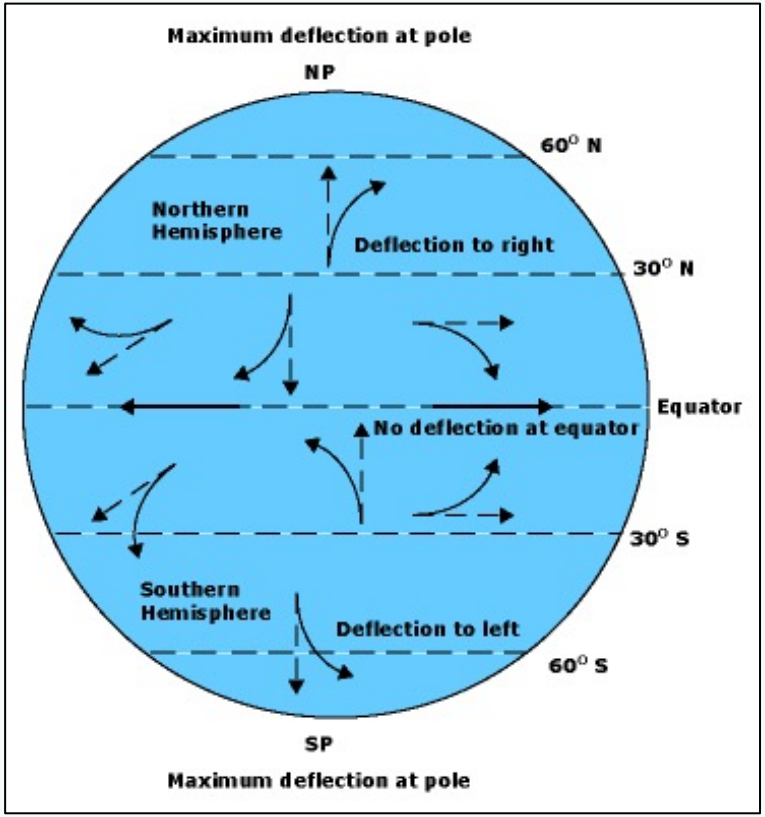
Opposite for the southern hemisphere

Test Your Knowledge

Buys-Ballot’s Law can be applied at the Equator. True or False?

Test Your Knowledge

Buys-Ballot's Law can be applied at the Equator.
False



Air masses

A large volume of air with similar temperature and moisture content.

Moisture properties:

maritime (wet)

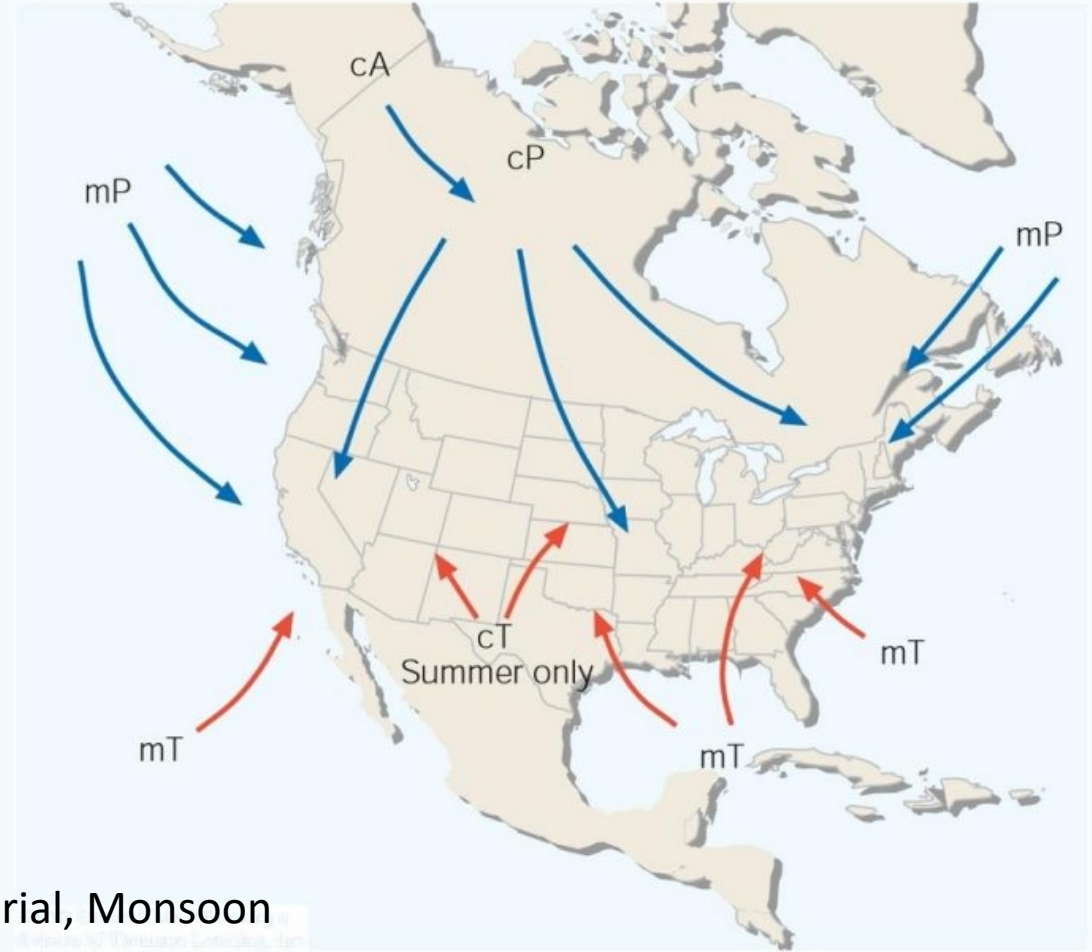
continental (dry)

Thermal properties:

Tropical

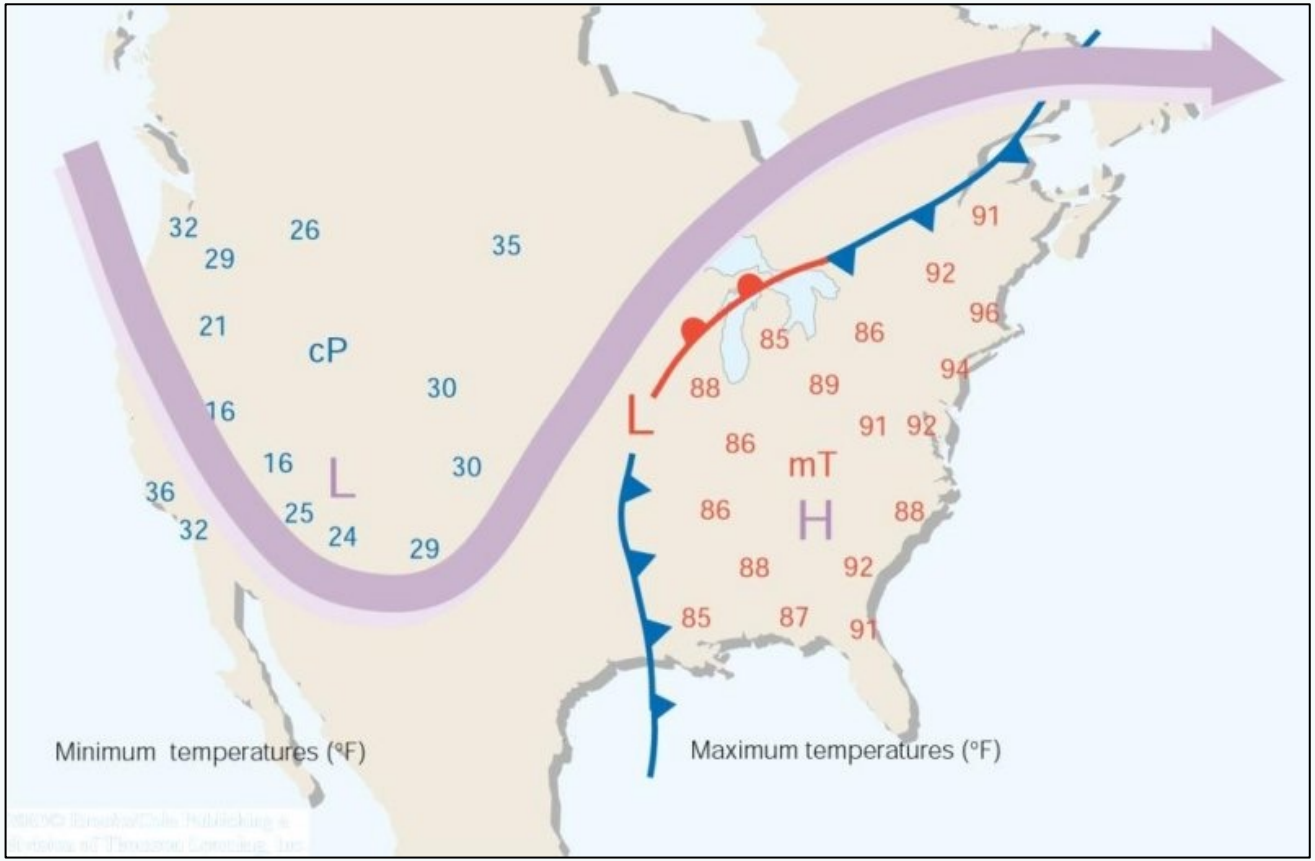
Polar

Arctic



Other thermal: Antarctic, Equatorial, Monsoon

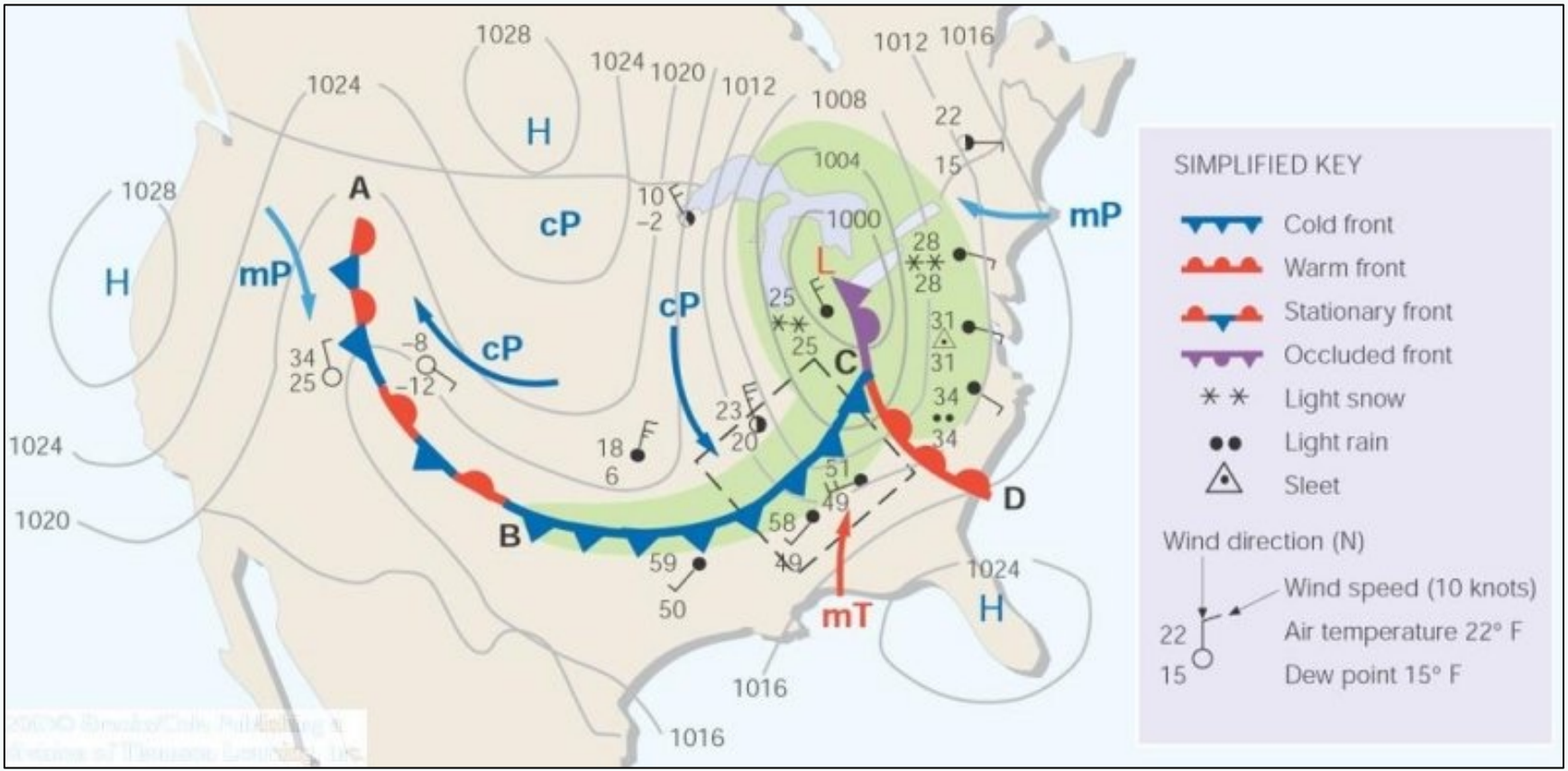
Fronts between air masses



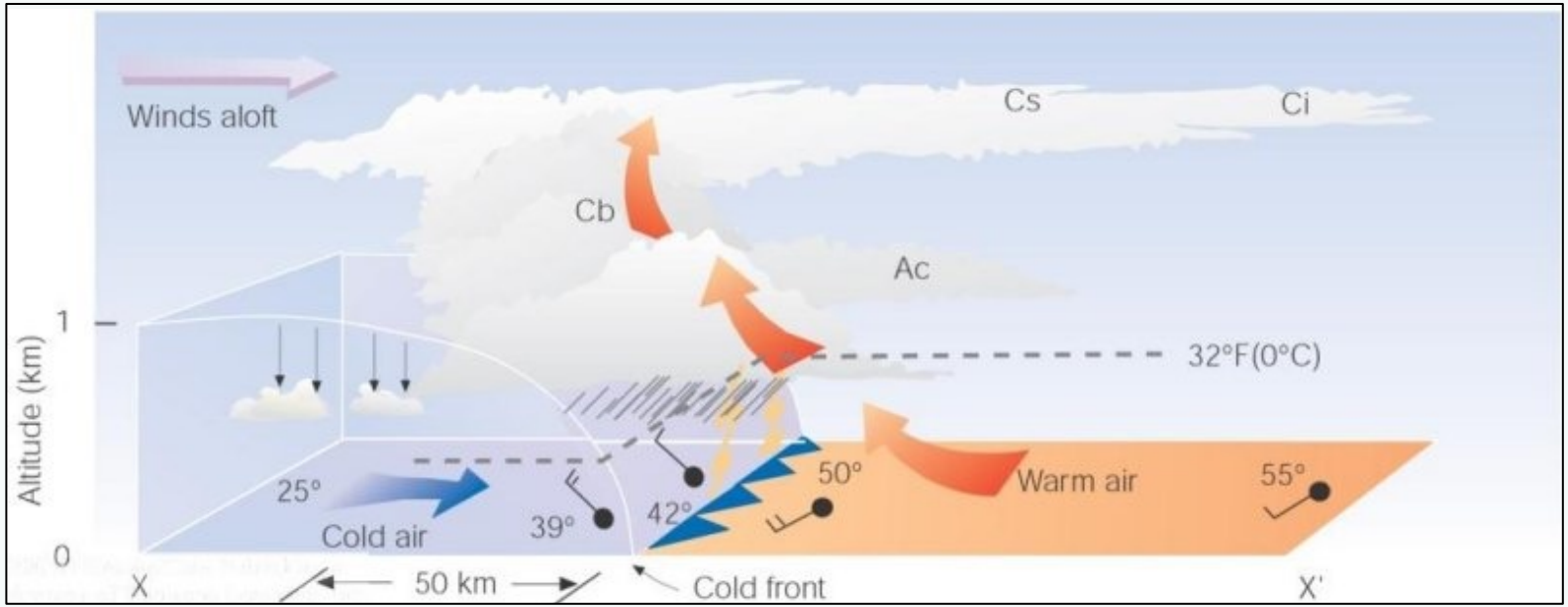
Boundary between air masses of different types or origins

Located along low pressure troughs

Weather Symbols

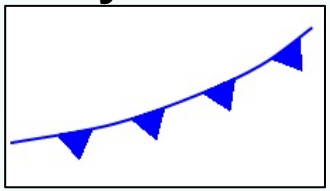


Cold Front

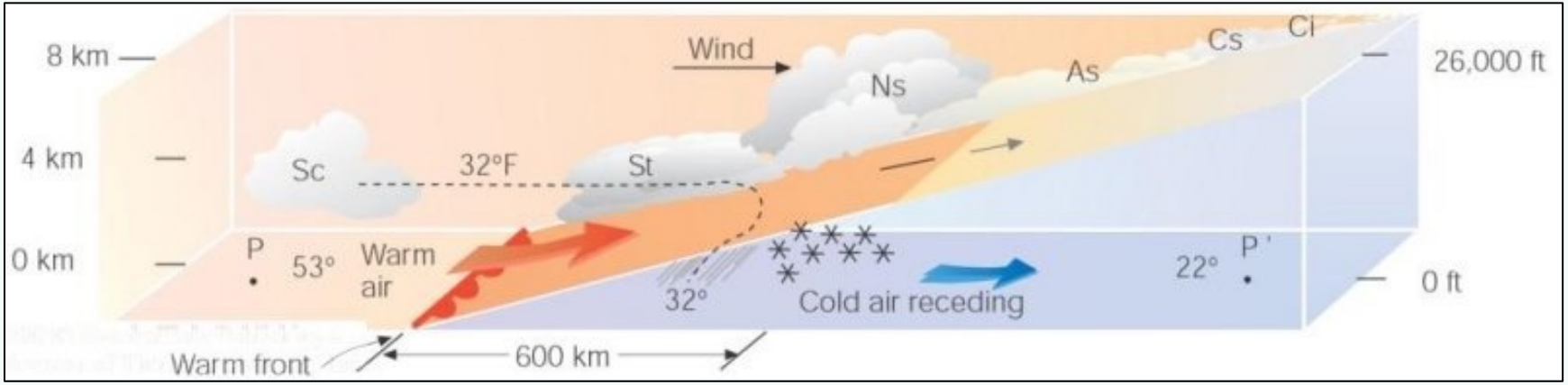


- Cold air mass catches up to warm air mass
- Forces warm air up, causing clouds
- Often associated with heavy thunderstorms, rain and hail

Symbol:

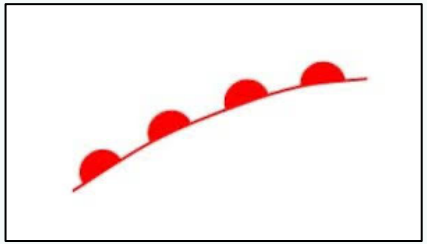


Warm Front



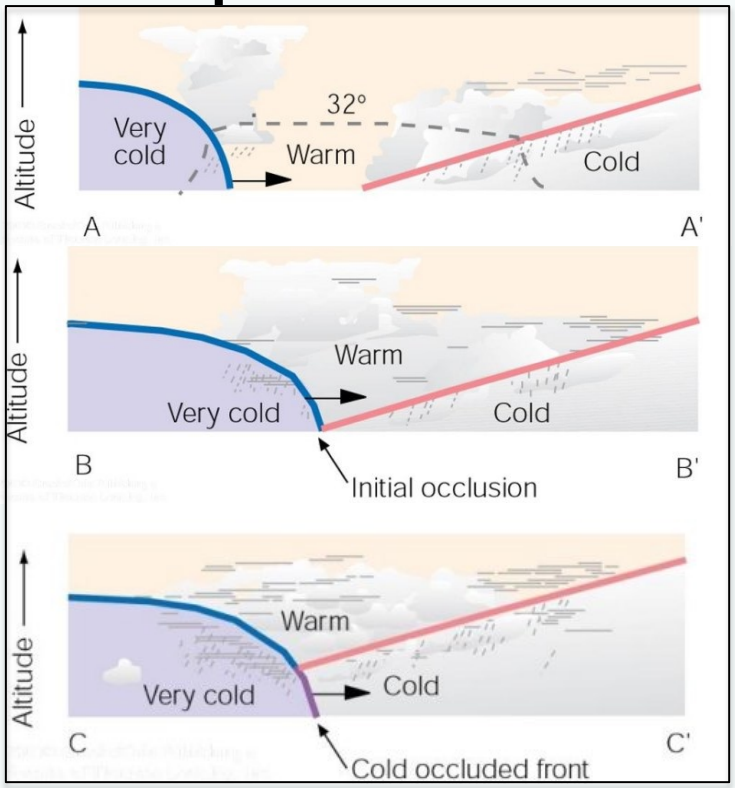
- Located at the leading edge of a warm air mass
- Warm air slowly overtakes cold air ahead of the front
- Warm air climbs over the cold air
- Stratiform clouds (sheets of clouds) form and rainfall increases as front approaches

Symbol:



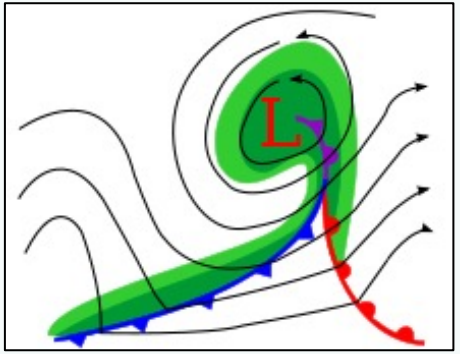
Occluded Front

Temporal Evolution

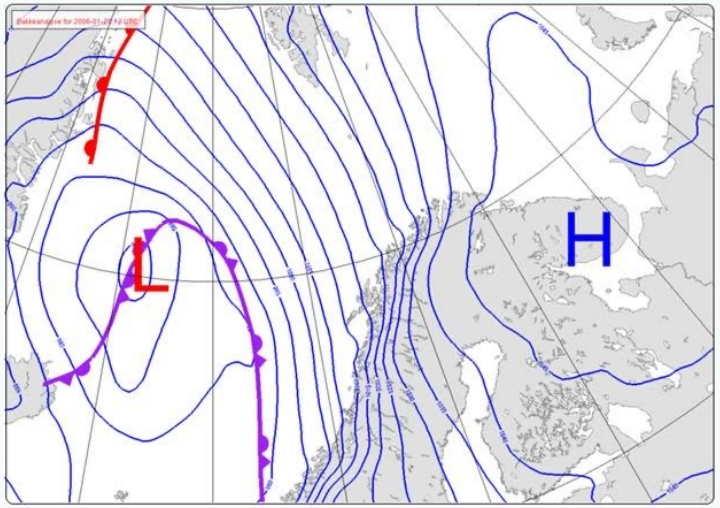


- Cold air overtakes warm air
- Usually forms around mature cold fronts
- Cold and warm fronts curve poleward into the point of occlusion (triple point)
- Wide range of weather along this front

Depiction on a weather map:



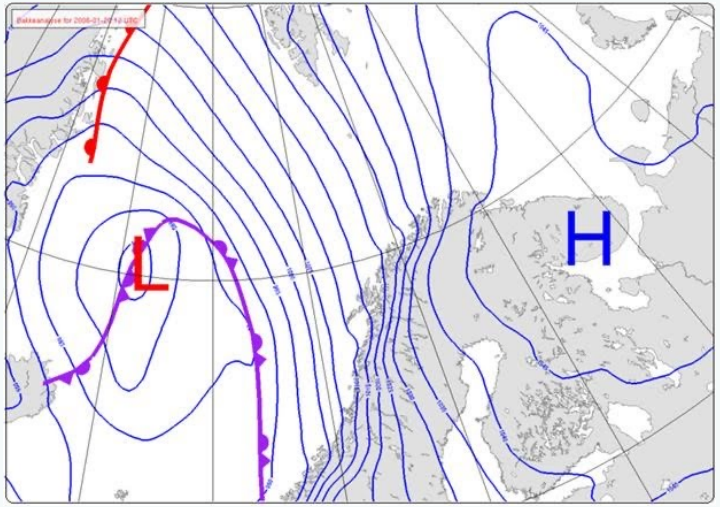
Test Your Knowledge



What is the approximate geostrophic wind direction over Norway in the accompanying contour map?

A. East to West
B. West to East
C. North to South
D. South to North

Test Your Knowledge



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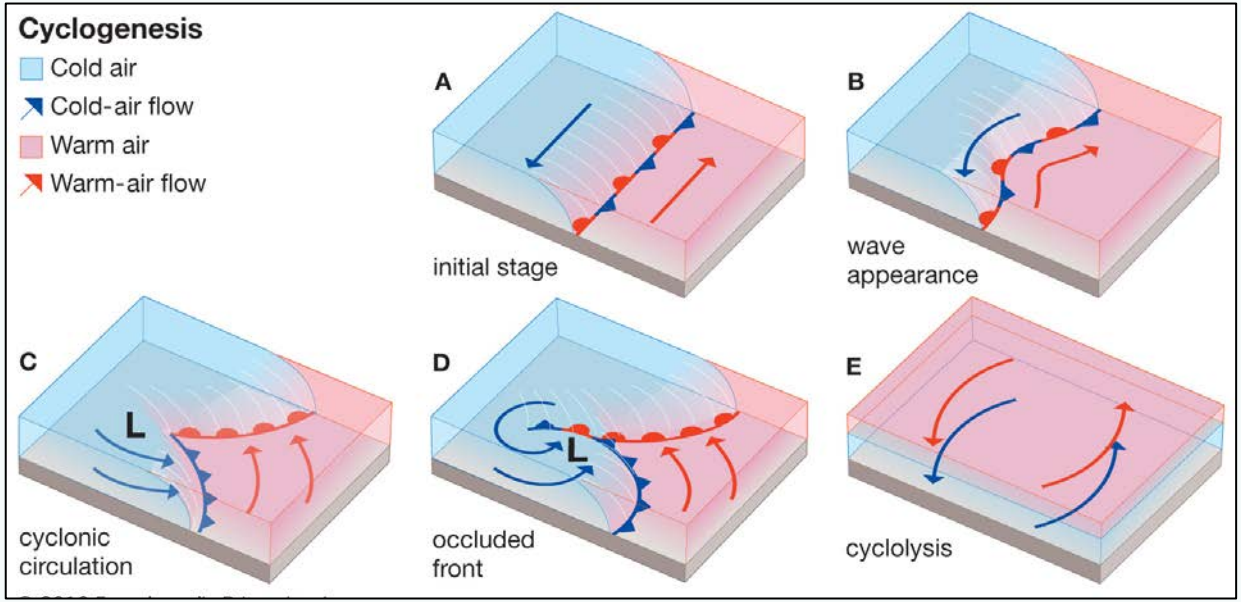
Cyclogenesis and cyclolysis



Development of cyclonic circulation

Leads to convection and clouds

Starts by disturbance along a stationary front

Distorts the front

Cyclonic flow intensifies as pressure within disturbance decreases

Forces warm air poleward and cold air equatorward

Opposite is cyclolysis (weakening of cyclonic flow)

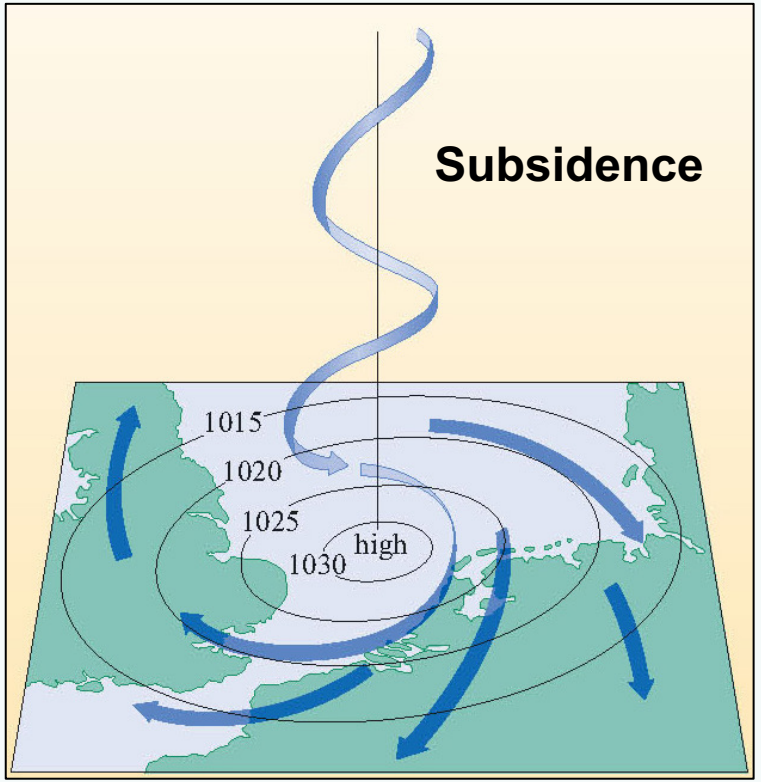
Anticyclogenesis and anticyclolysis

Development or strengthening of anticyclonic flow around a high pressure system

Opposite of anticyclolysis: weakening of anticyclone

Anticyclones:

- No or low clouds
- Brings continental air masses to the UK
- Cold in winter, warm in summer



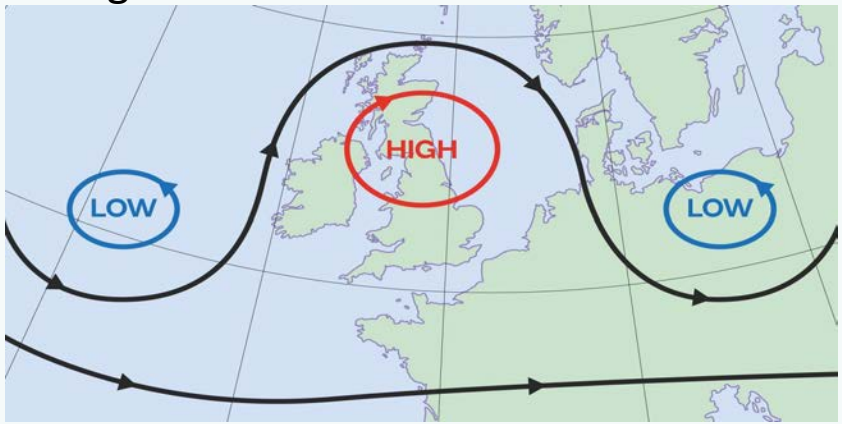
Blocking

Large high pressure air mass remains stationary over the same period for a long time (week or more)

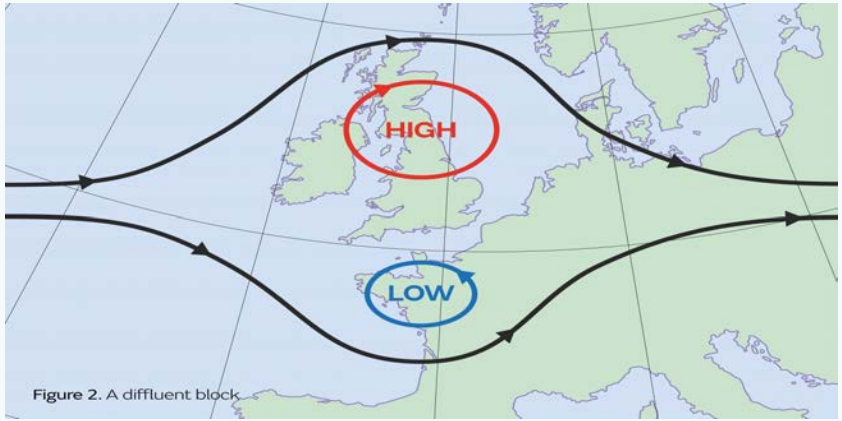
Blocks or redirect migratory cyclones and fronts

Can cause sustained heatwaves or cold conditions over the UK

Omega Block

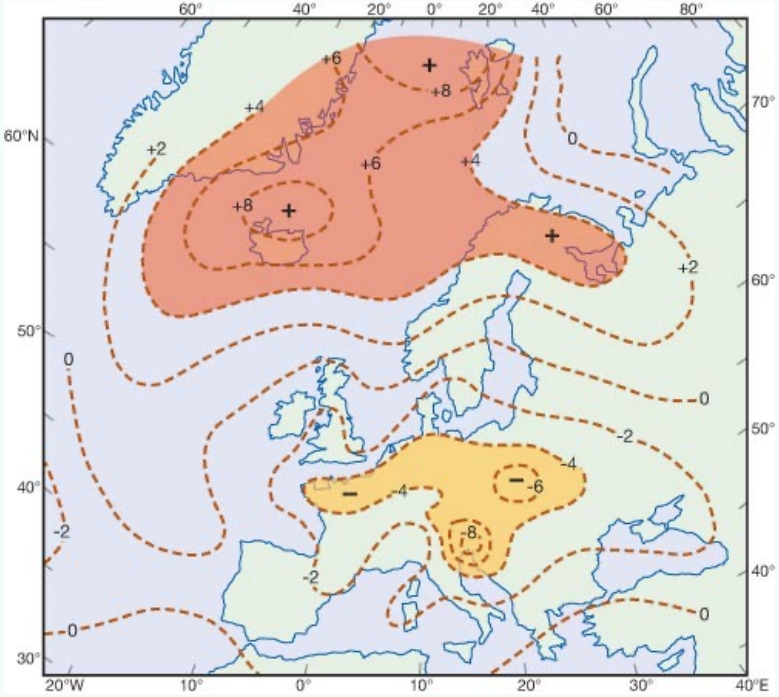


Diffluent Block



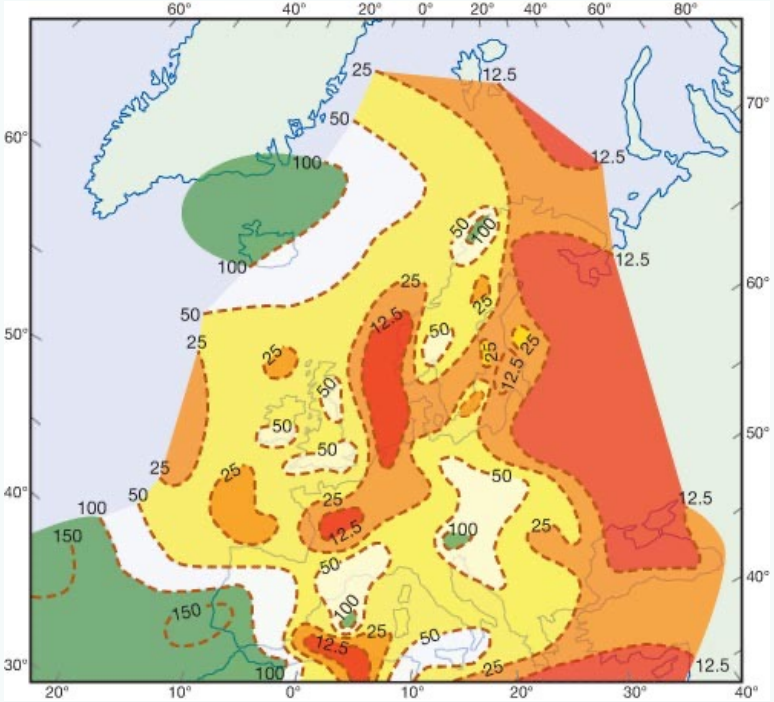
Impact of Blocking

Winter Temperature (°C)



Lower than average over Europe

Winter Rainfall (% of normal)



Less than average over most of Europe

Summary

- Important Concepts:
  - Atmospheric Pressure
  - Coriolis Effect
- Synoptic (large-scale) meteorology
  - Cyclones and Anticyclones
  - Fronts
  - Blocking
- How to read a weather map
- *Thursday: Climate*