DEPARTMENT OF GEOGRAPHY

The Atmosphere

Geog0005

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

The Atmosphere

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

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 Layers

Troposphere: Where Earth's weather occurs

ASIDE

Key physical concepts

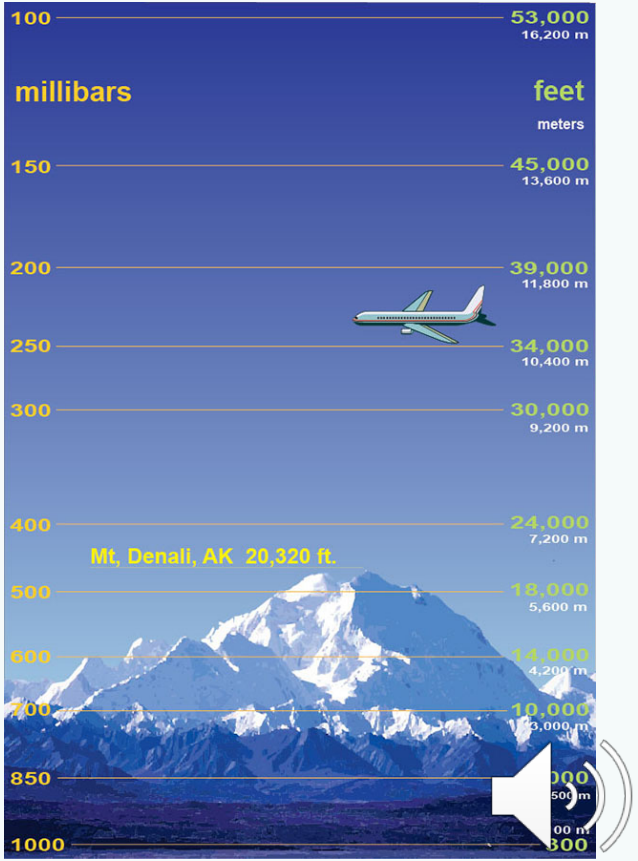
Atmospheric Pressure

gravitational constant (10 m/s^2)

Pressure ($Pa, kg/ms^2$) → **P = ρgh** ← height above surface (m)

air density (kg/m^3)

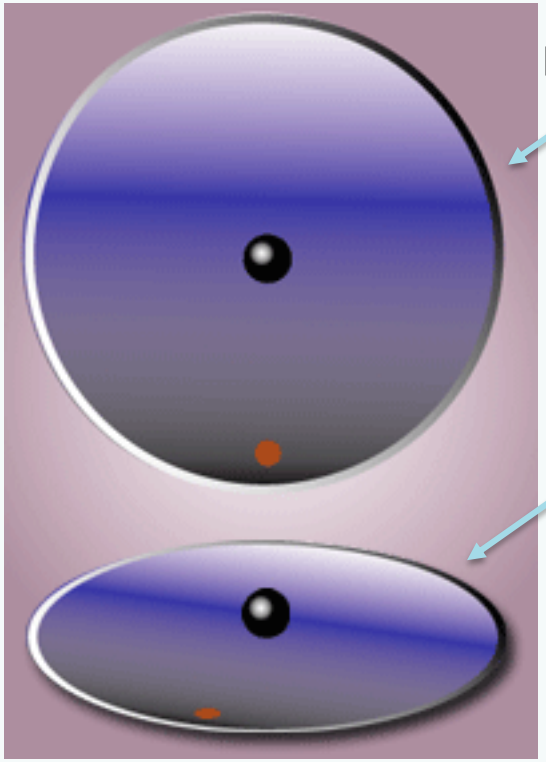
- Measured in millibars (mb)
  - 1 mb = 100 Pa = 1 hPa
  - Average sea level pressure is 1013 mb
- Air density decreases with altitude
  - Most air molecules held tightly to surface (gravity)
  - Pressure decreases with altitude



Reference Frames

- A reference frame describes where we look at dynamics from
- But the reference frame is moving too (due to Earth's rotation). 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



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**

Coriolis Effect

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

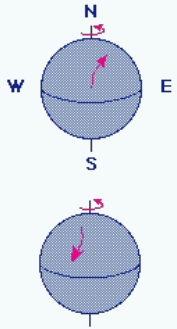
$$F = ma = m\ 2\Omega\ |U| = m\ 2\Omega\ v'$$

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

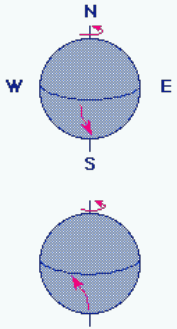
Deflection of air parcel

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

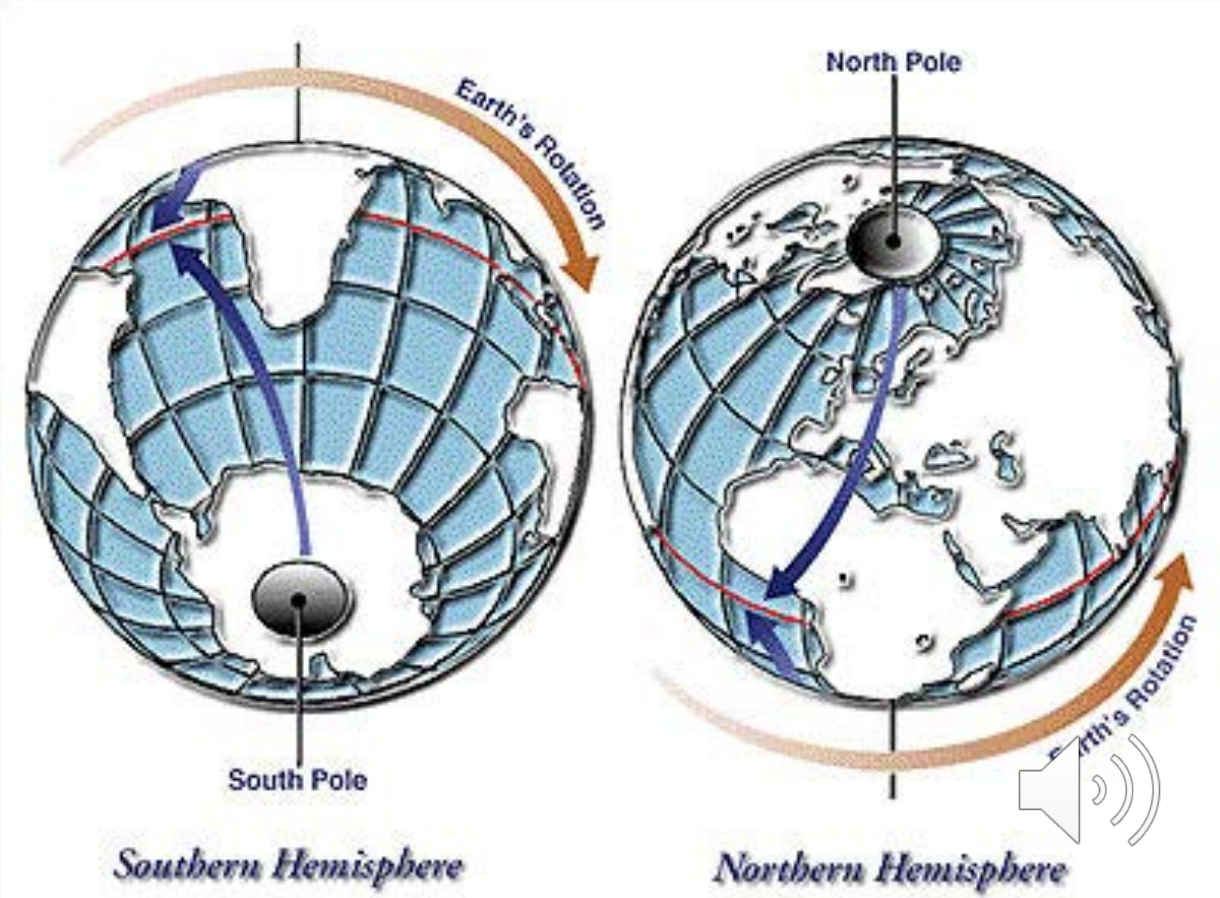
To the **left** in the **southern hemisphere**



Deflection to the right in the Northern Hemisphere



Deflection to the left in the Southern Hemisphere



Coriolis Force Multiple Choice

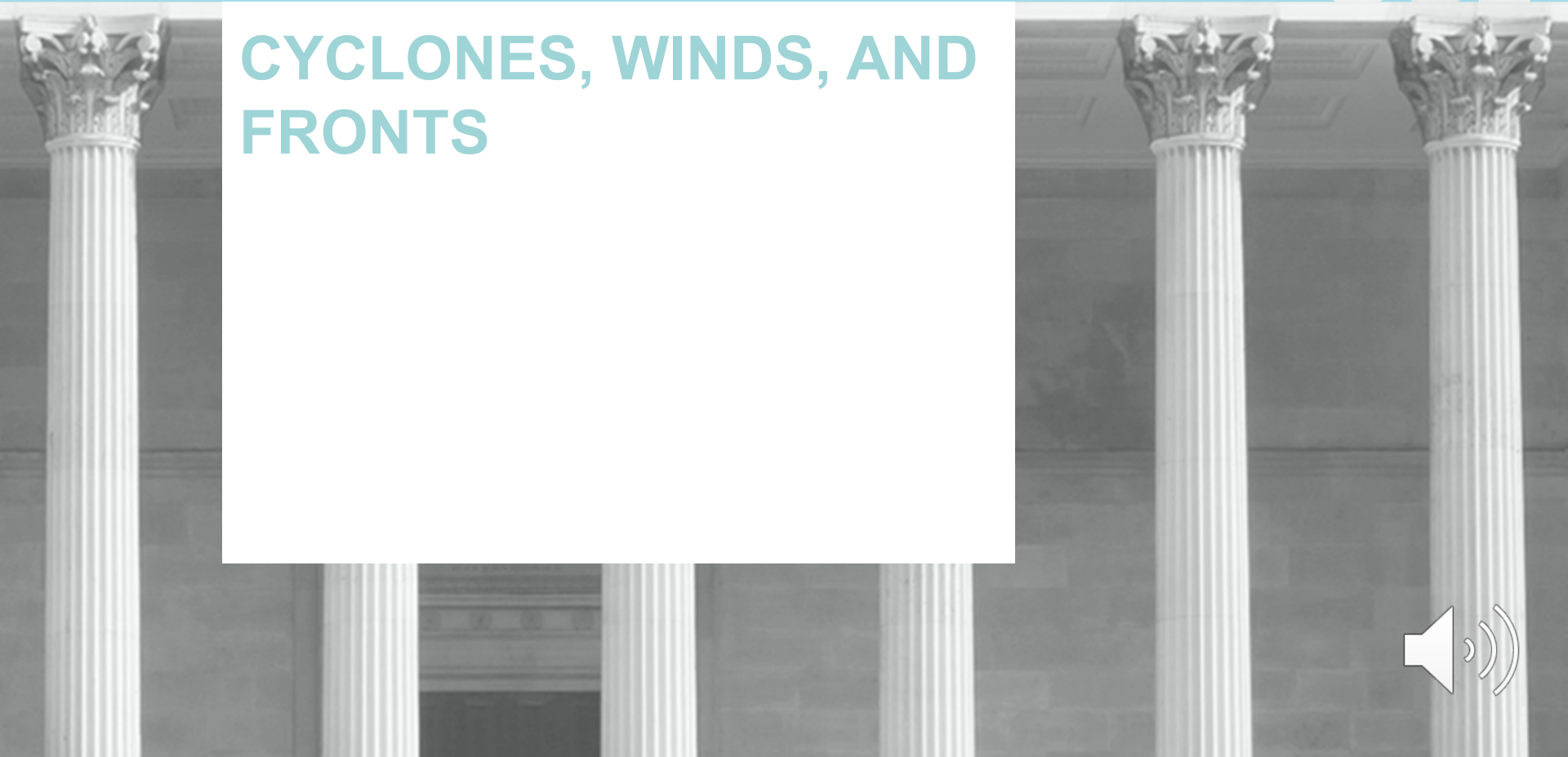
If you throw a paper plane in a straight line due north from London on a calm day, the plane will:

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

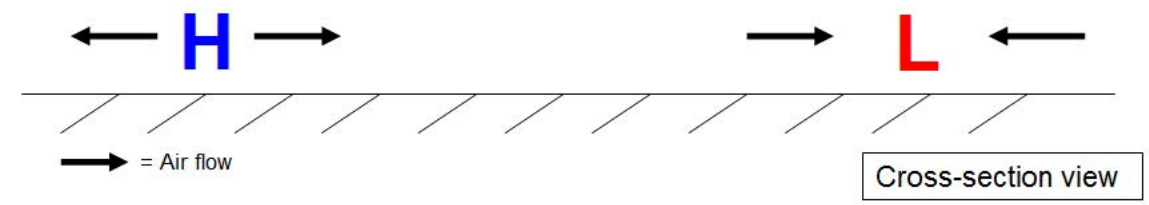
A storm spins _____ in the northern hemisphere and _____ in the southern hemisphere:

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

CYCLONES, WINDS, AND FRONTS



Air moves along the gradient from high to low pressure

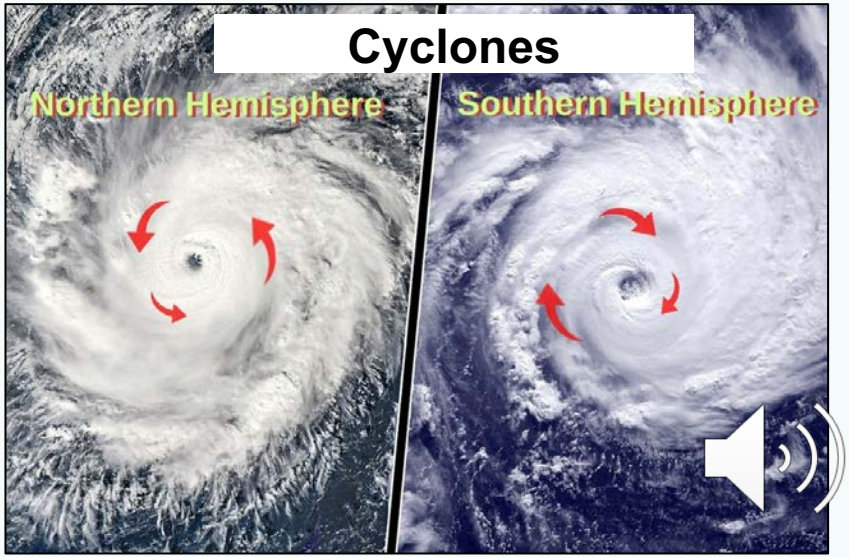


And is deflected due to the Coriolis effect

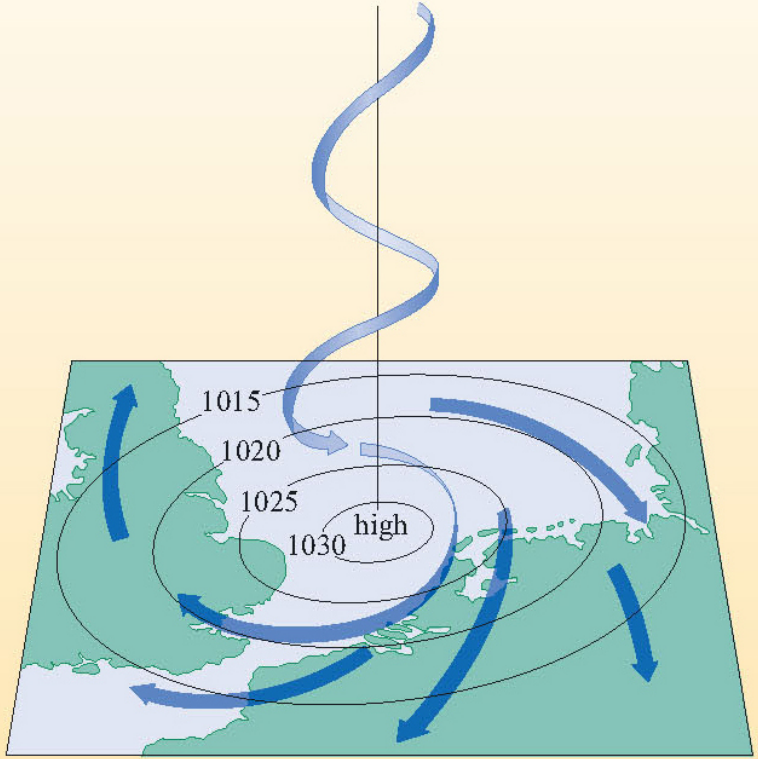
Cyclones

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

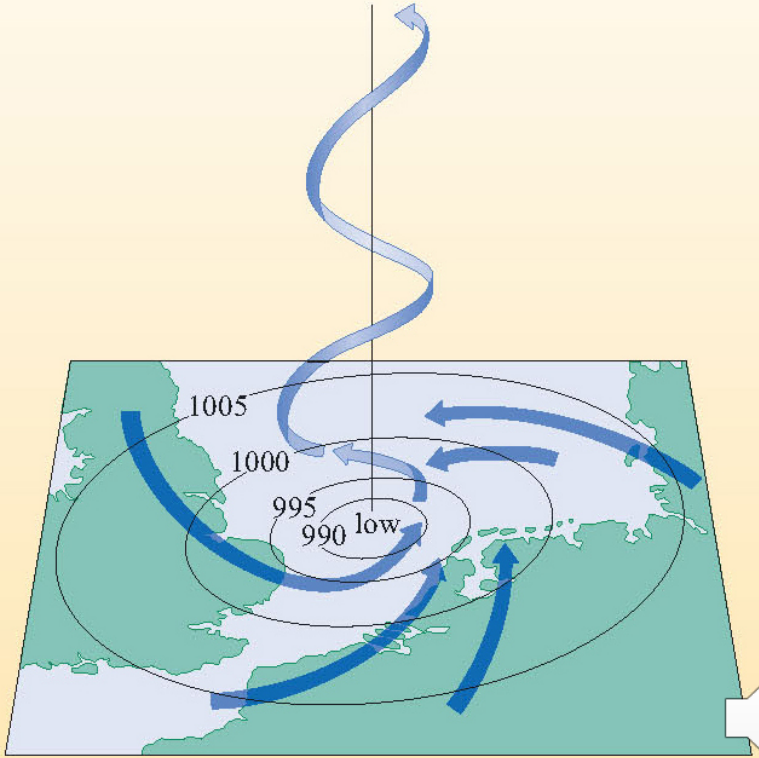
- Anticyclone: air spins outward from high to low pressure



Example high and low pressure systems over UK



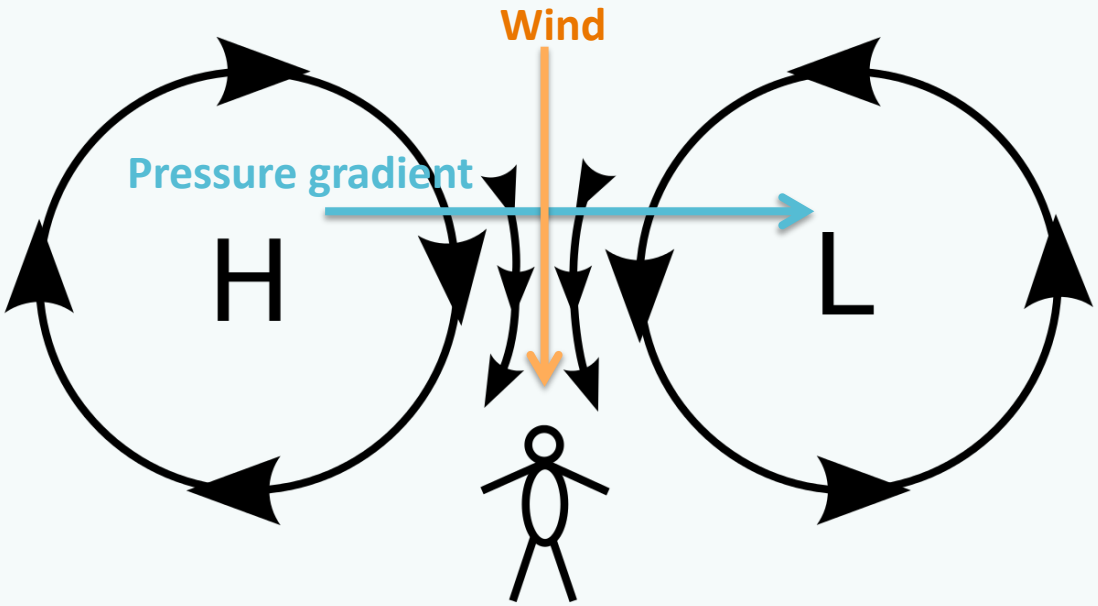
(a) **Anticyclone (High)**



(b) **Cyclone (Low)**

Buys-Ballot's Law

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



In a frictionless atmosphere and due to the Coriolis effect…

The angle between the wind and pressure gradient is at 90^{o}

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

Opposite for the southern hemisphere

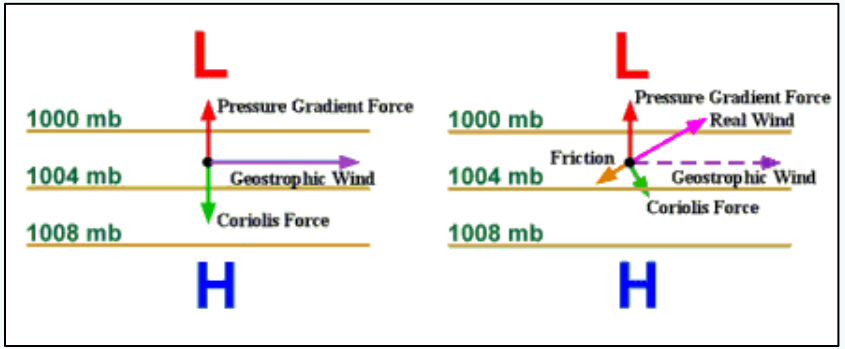
Surface Winds and Friction

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

Ignores friction

Geostrophic wind flows parallel to isobars

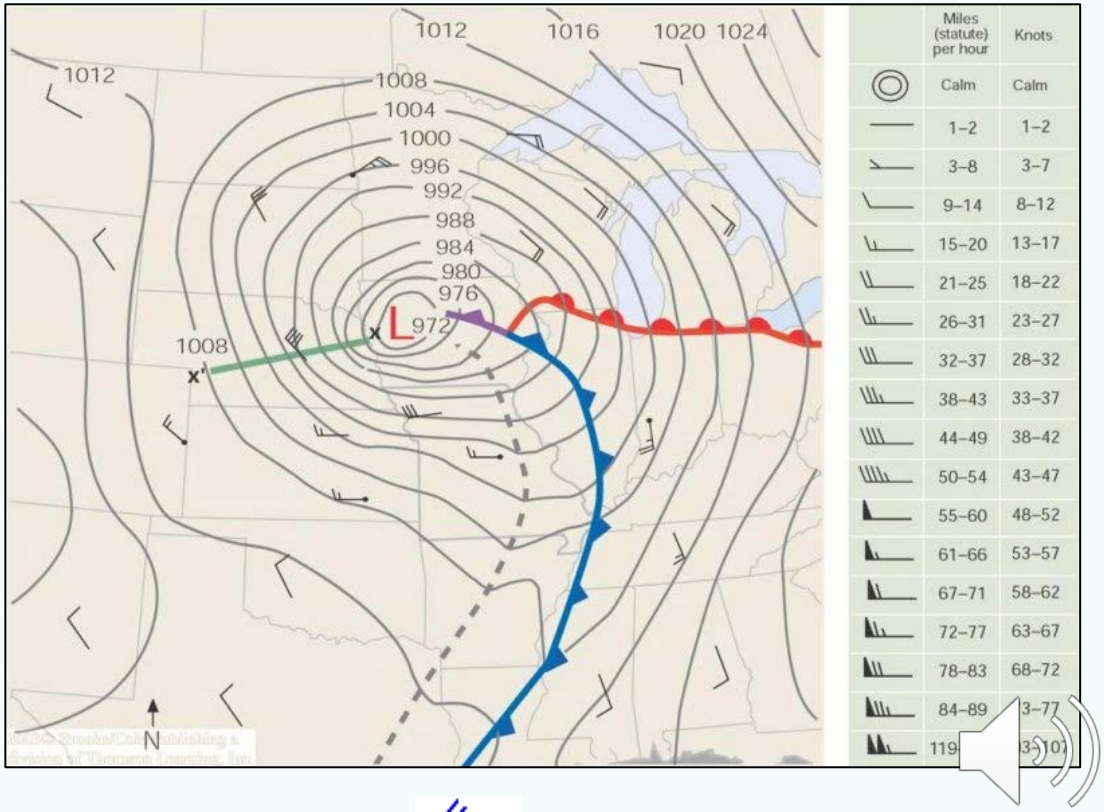
Friction and Coriolis effect deflect wind



Horizontal lines are **isobars**: lines of constant pressure at a given height

Surface Winds

Closer isobars →stronger pressure gradient → faster wind speed



Wind “barbs”  show wind speed

Air masses

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

Moisture properties:

maritime (wet)

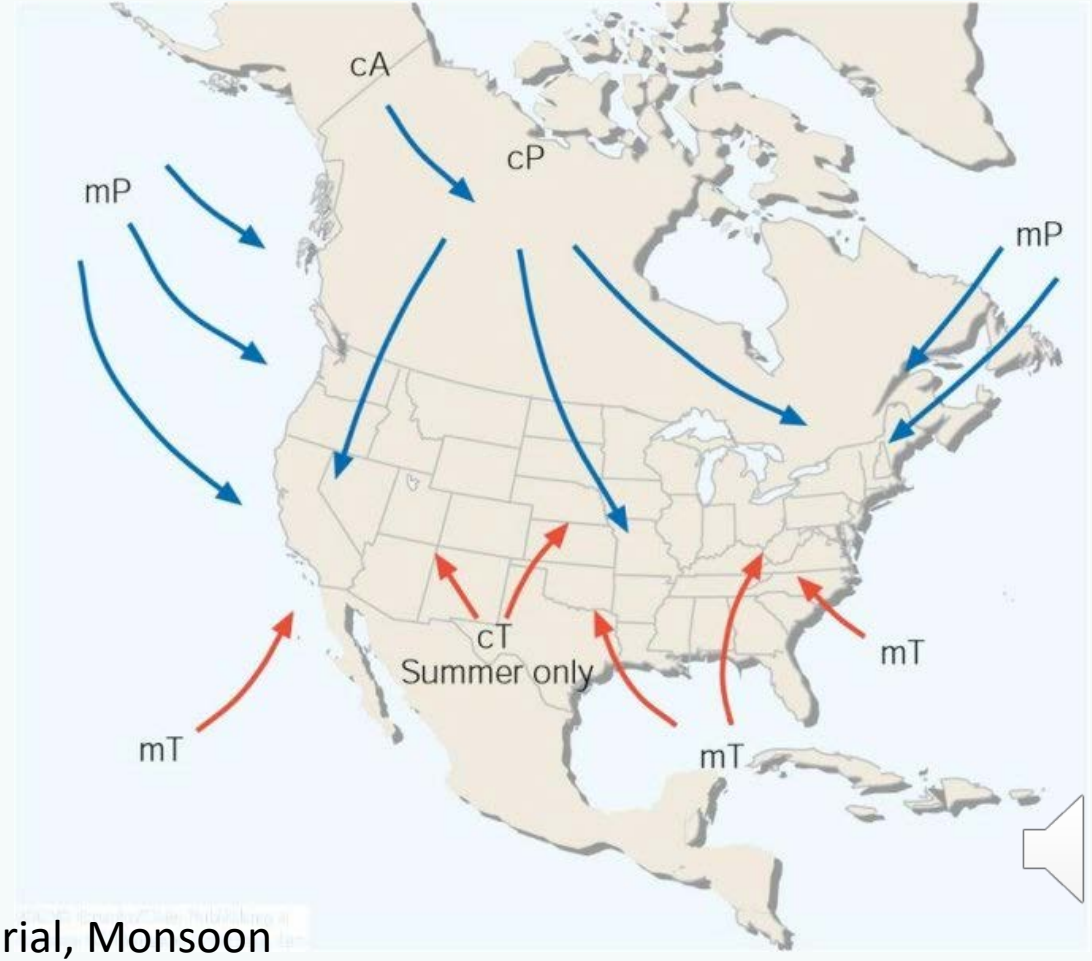
continental (dry)

Thermal properties:

Tropical

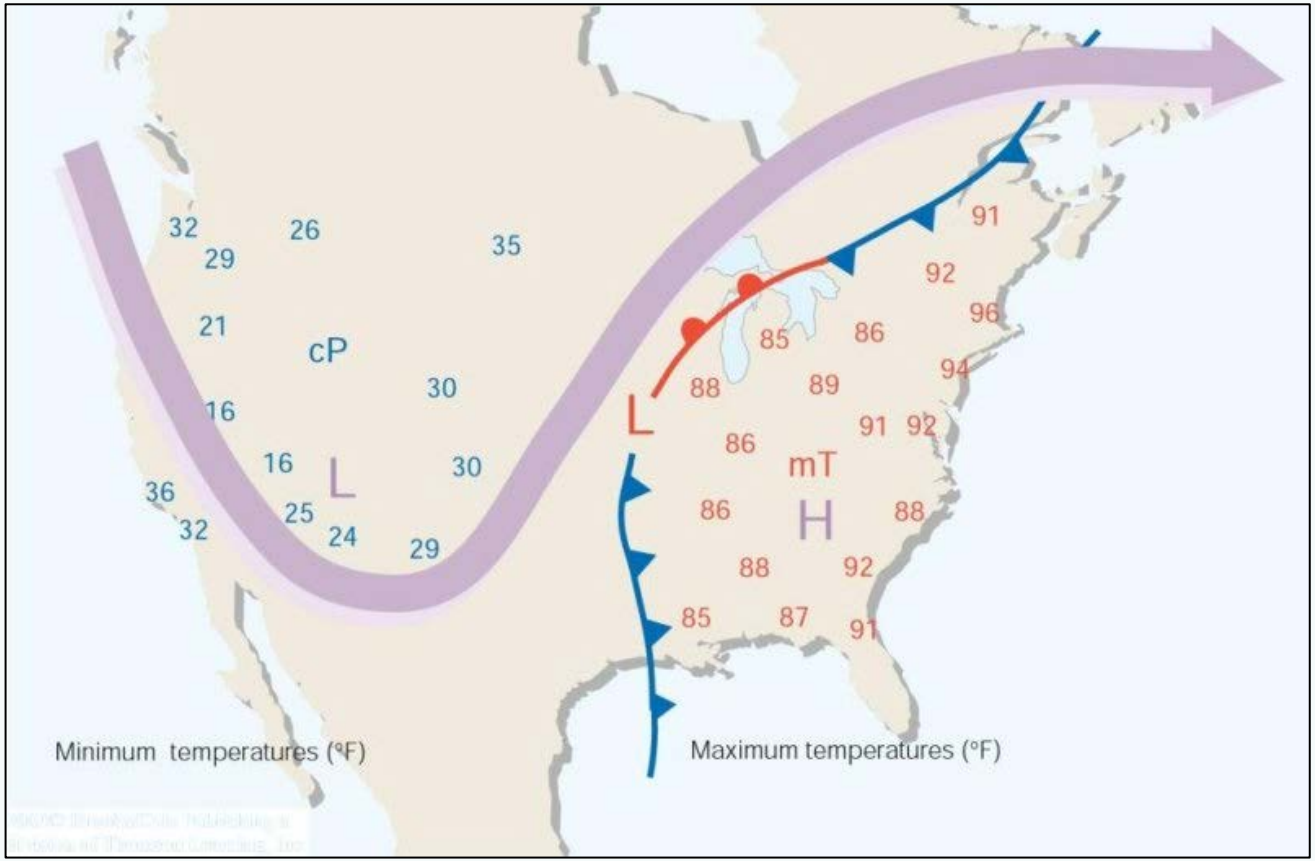
Polar

Arctic



Other thermal: Antarctic, Equatorial, Monsoon

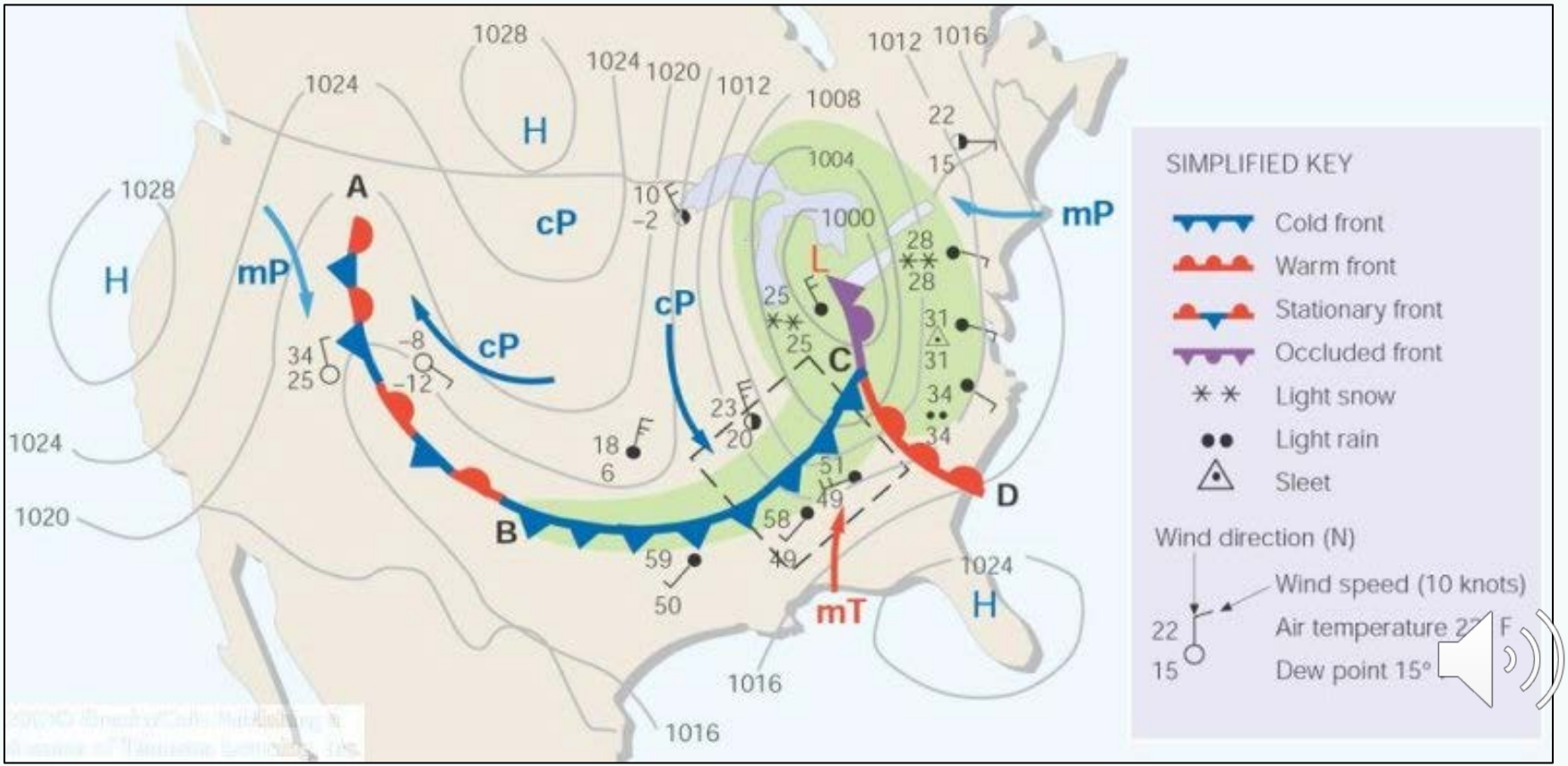
Fronts between air masses



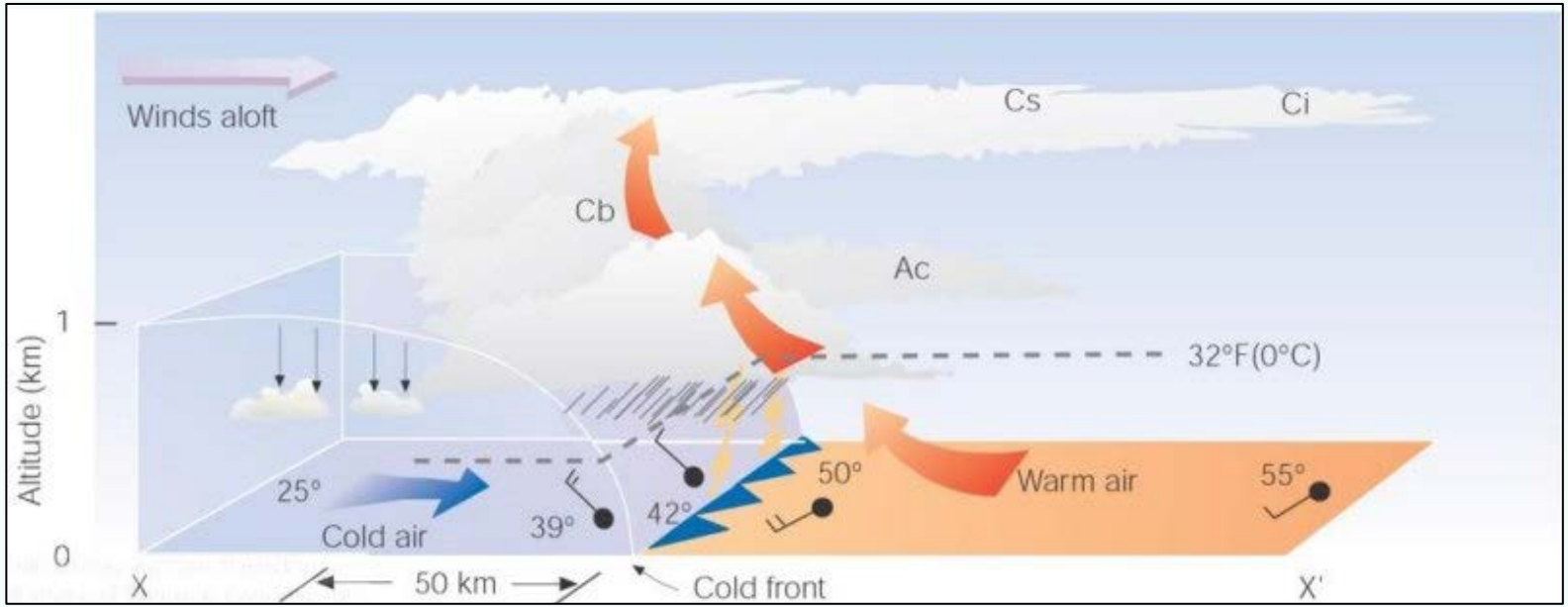
Boundary between air masses of different types or origins

Located along low pressure troughs

Weather Symbols

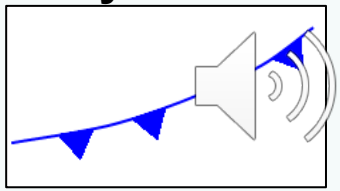


Cold Front

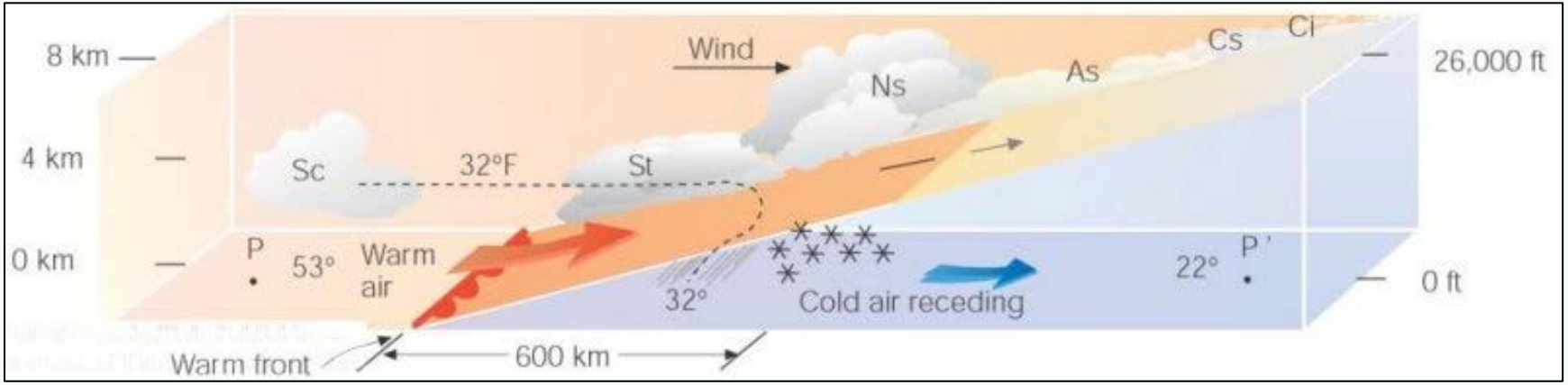


- Cold air mass catches up to warm air mass
- Forces warm air up, causing clouds
- Often associated with heavy thunderstorms, rain and hail

Symbol:

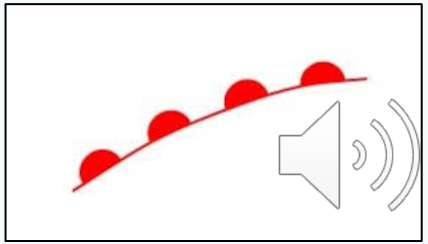


Warm Front



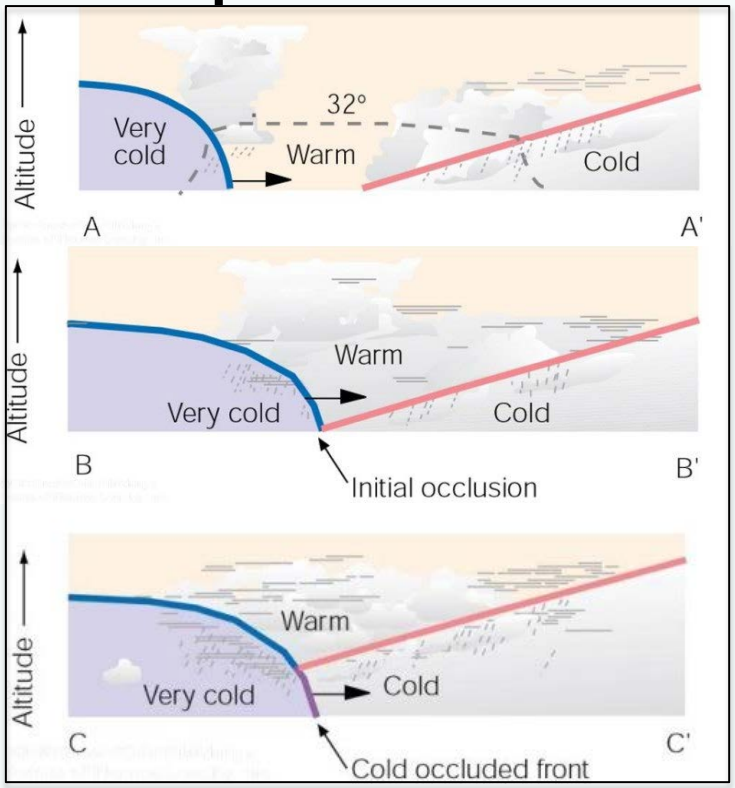
- Located at the leading edge of a warm air mass
- Warm air slowly overtakes cold air ahead of the front
- Warm air climbs over the cold air
- Stratiform clouds (sheets of clouds) form and rainfall increases as front approaches

Symbol:



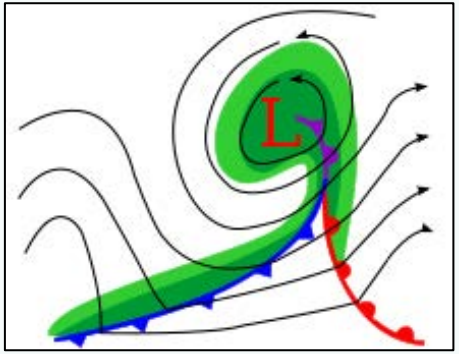
Occluded Front

Temporal Evolution



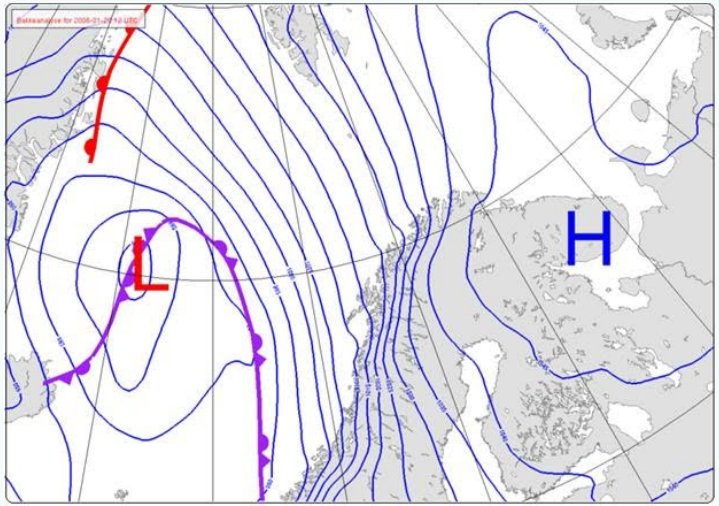
- Cold air overtakes warm air
- Usually forms around mature cold fronts
- Cold and warm fronts curve poleward into the point of occlusion (triple point)
- Wide range of weather along this front

Depiction on a weather map:



Test Your Knowledge

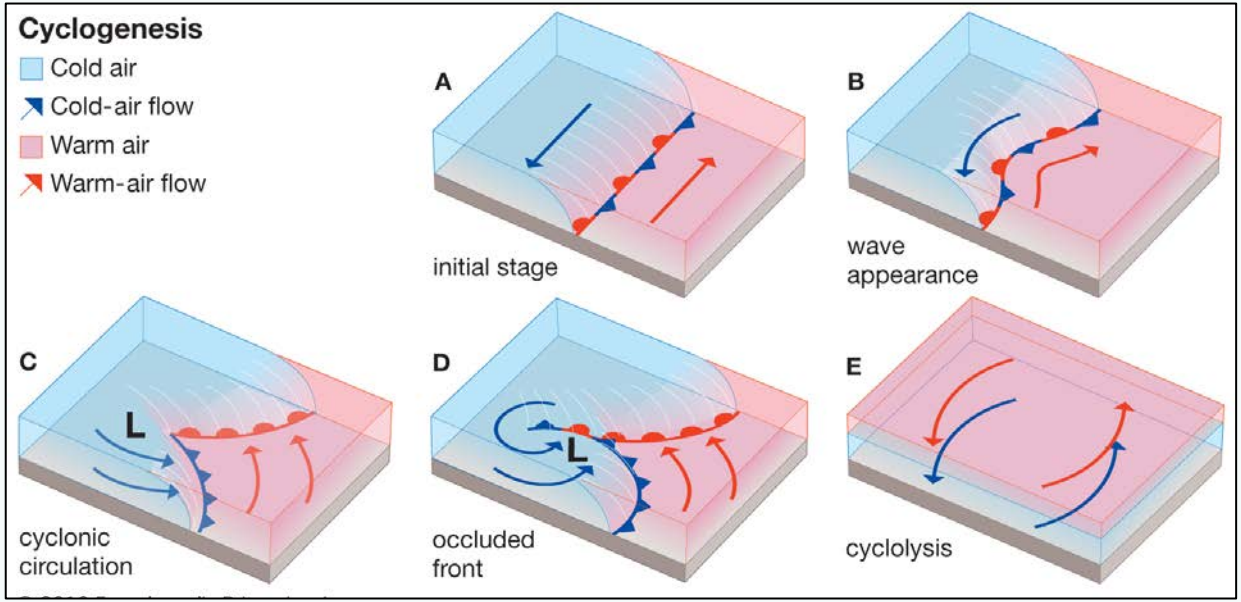
Buys-Ballot's Law can be applied in the tropics. True or False?



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

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)

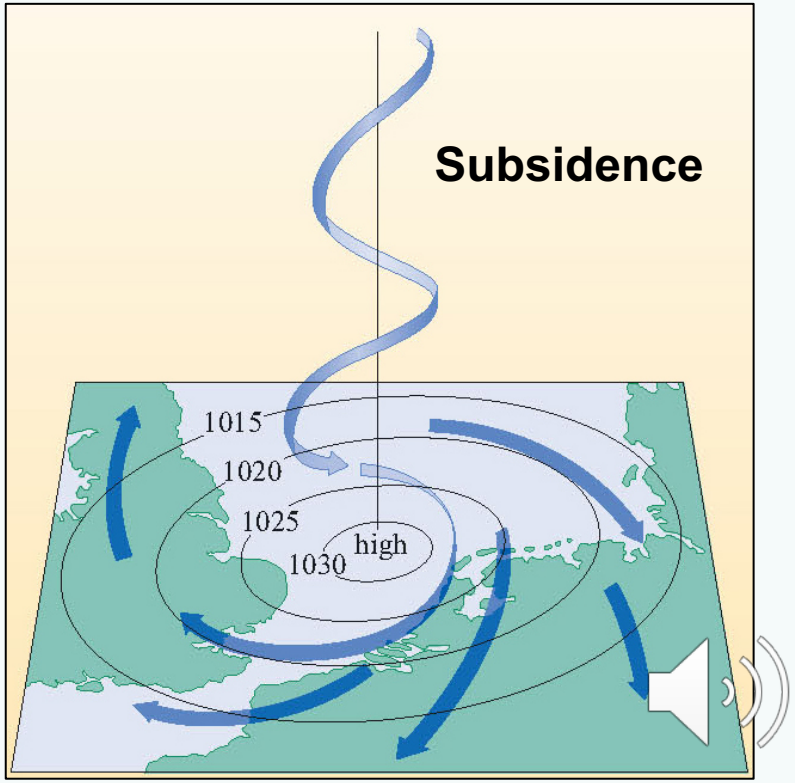
Anticyclogenesis and anticyclolysis

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



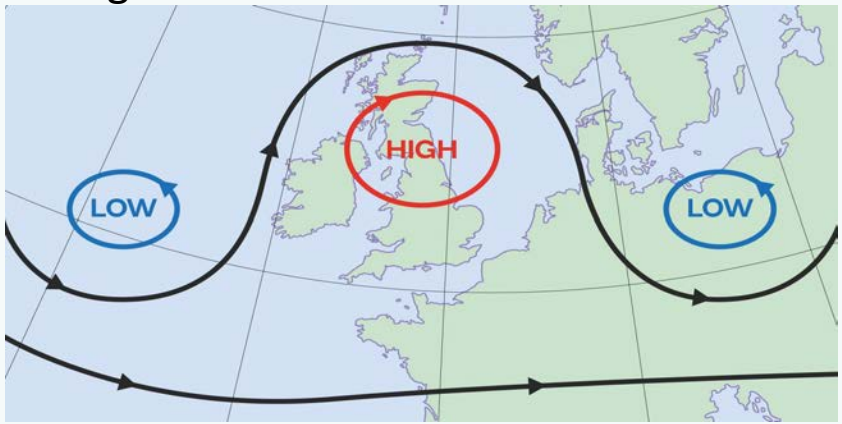
Blocking

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

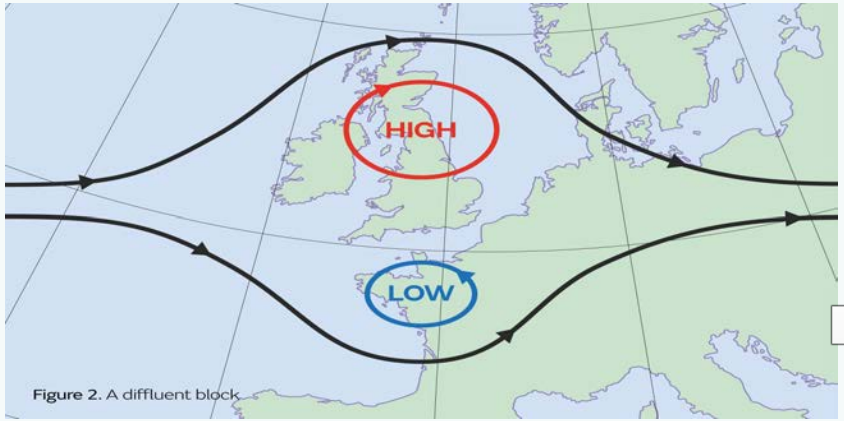
Blocks or redirect migratory cyclones and fronts

Can cause sustained heatwaves or cold conditions over the UK

Omega Block

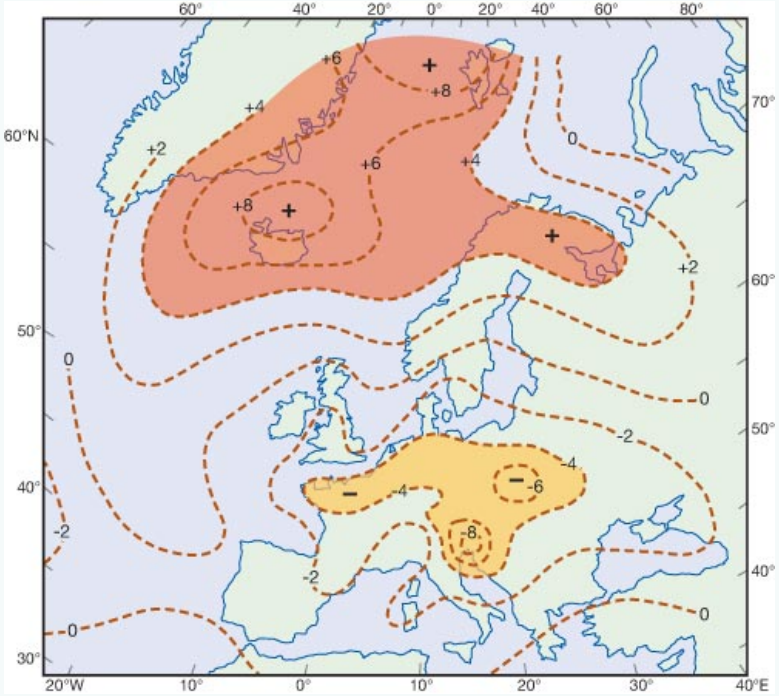


Diffluent Block



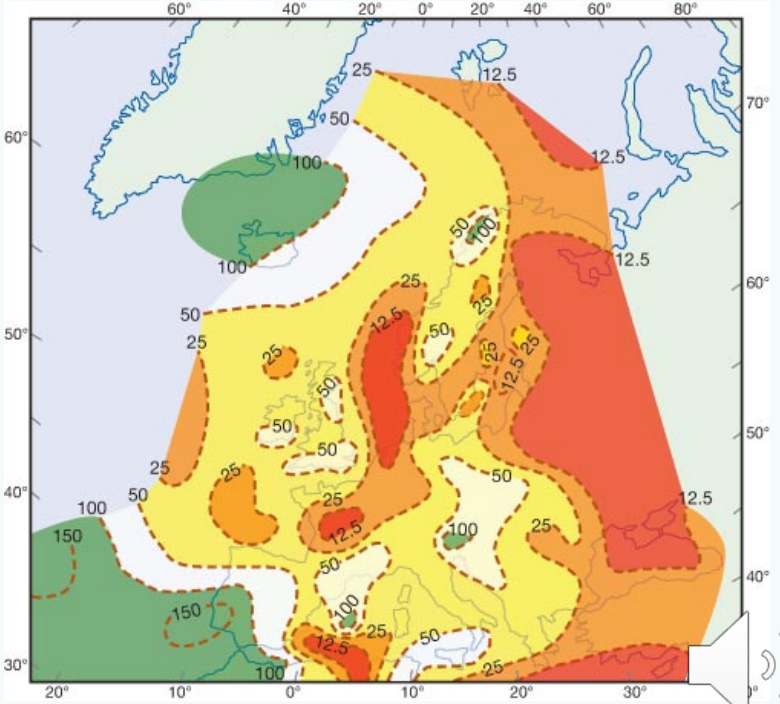
Impact of Blocking

Winter Temperature (°C)



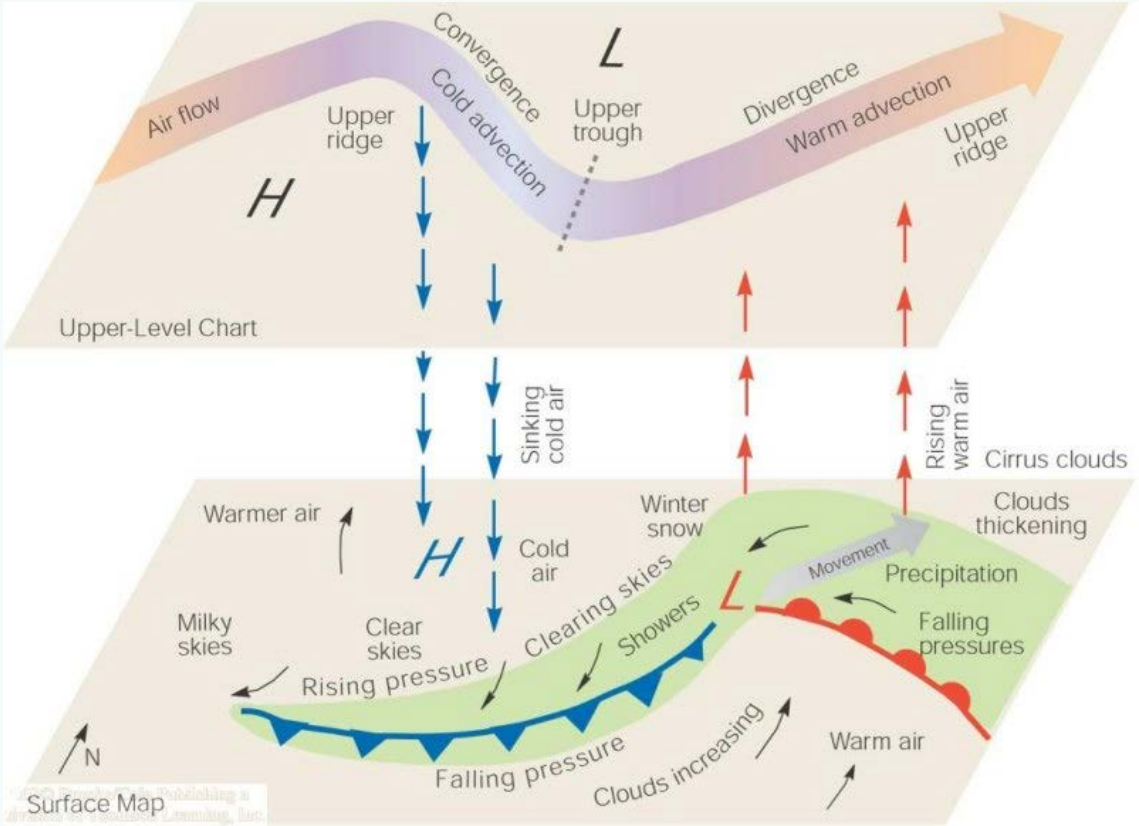
Lower than average over Europe

Winter Rainfall (% of normal)



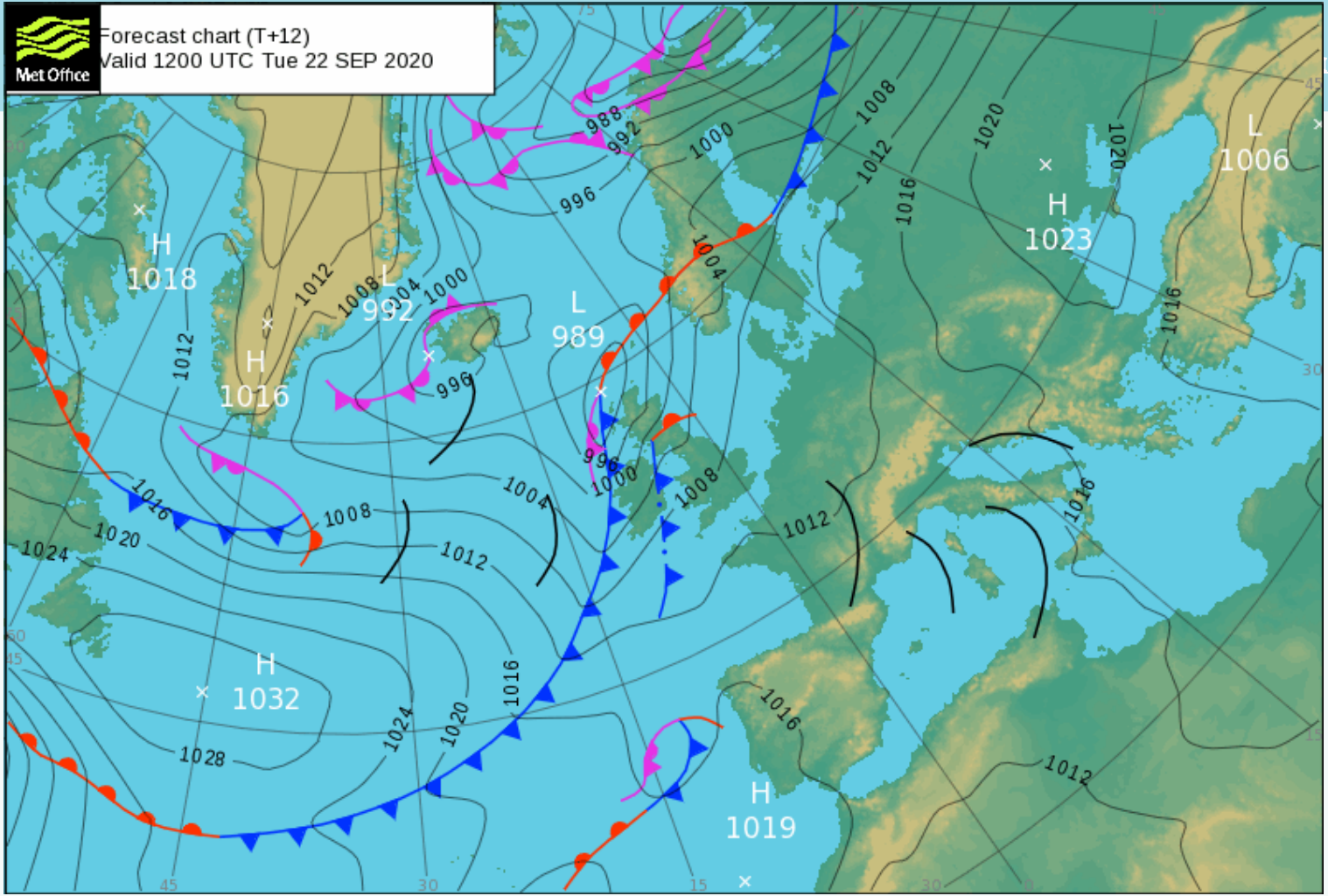
Less than average over most of Europe

Looking ahead: heat transport…



Summary

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


Met Office
Forecast chart (T+12)
Valid 1200 UTC Tue 22 SEP 2020
H
1018
H
1016
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1028
988
992
996

Homework: Multiple Choice

The weather system over the UK in the pressure (or synoptic) chart on the right can best be described as:

A. A stationary front
B. An anticyclone
C. An occluded front
D. A warm front

Conditions that are typically associated with this weather system are:

A. Fair and mild
B. Windy and rainy
C. Clear skies
D. Snowfall

Pressure chart for 25 September 2012