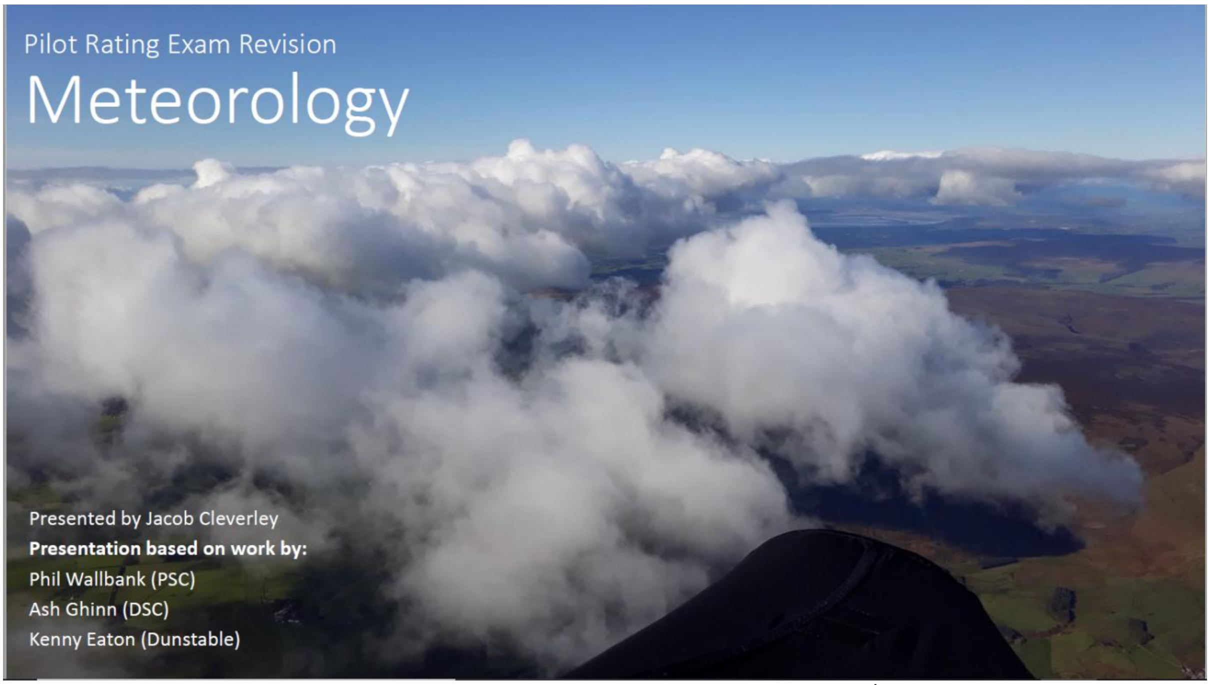
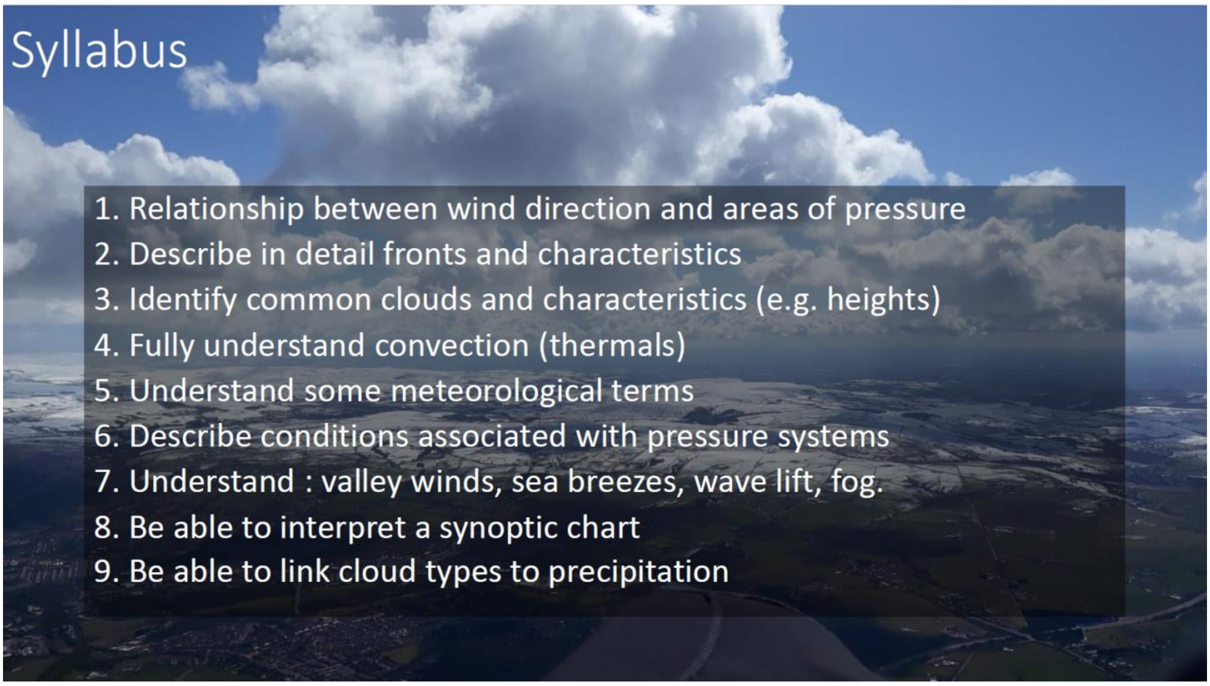
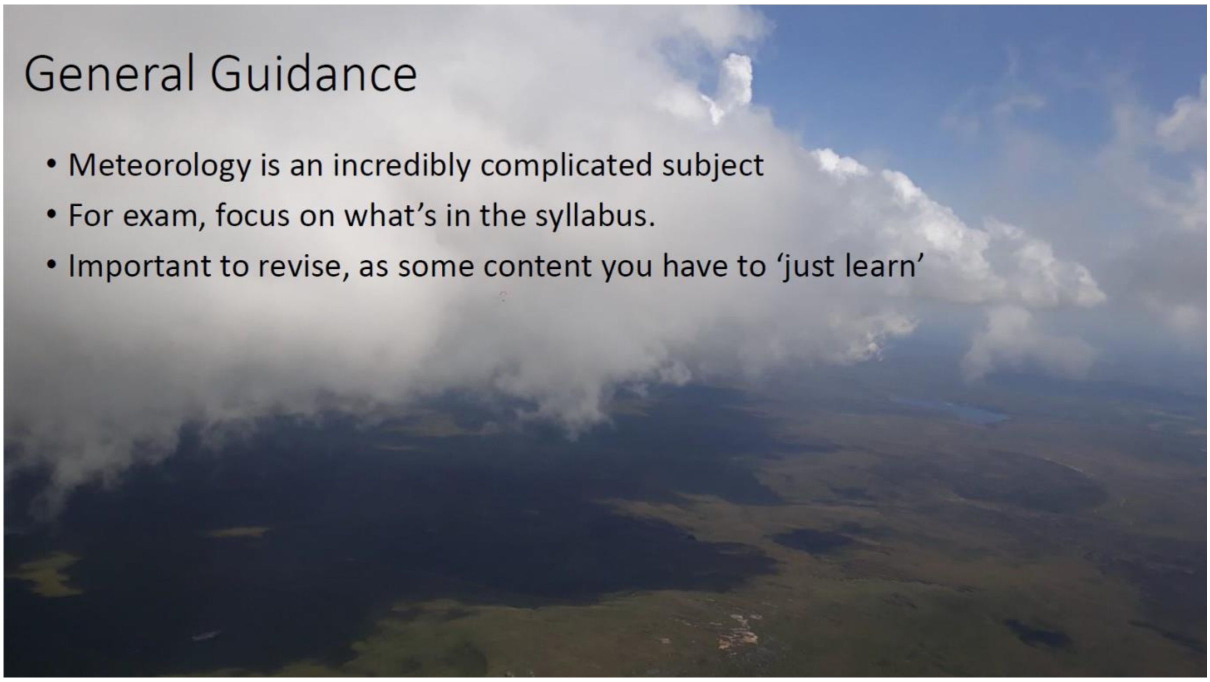


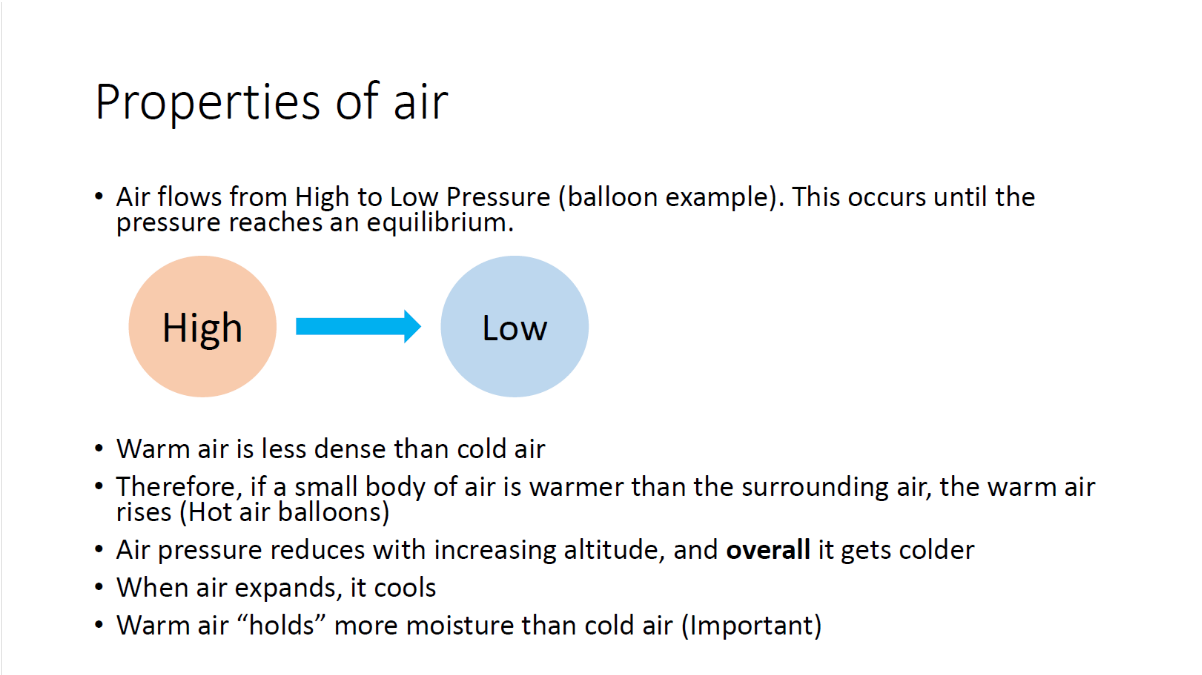
Background image taken during a flight from Longridge on 11th October 2020, at 5200ft, over 2000ft higher than cloudbase.



Background photo over the back of Longridge, April 2021.



Massive convergence line over the back of Dodd, 40km at over 6000ft alongside this.

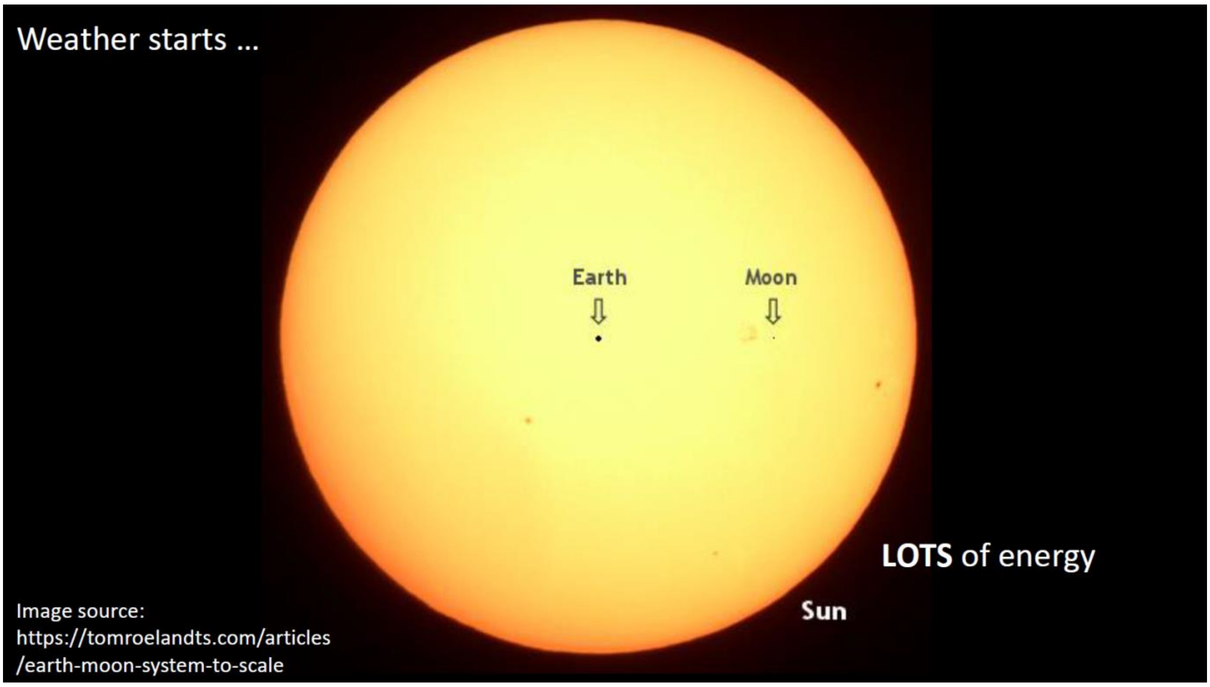


Properties of air – not part of exam, but somewhat useful to know. Detail below in italics not really necessary.

Pressure - Think about a balloon when you leave the end open – the air flows from inside the balloon (high pressure) to outside (lower pressure) until the pressure is equal inside and outside of the balloon

Warm air is less dense because warm air molecules have more energy, and therefore move around faster with more energy. This means that the molecules move apart, and for a given volume there are fewer air molecules, so the warmer air is less dense.

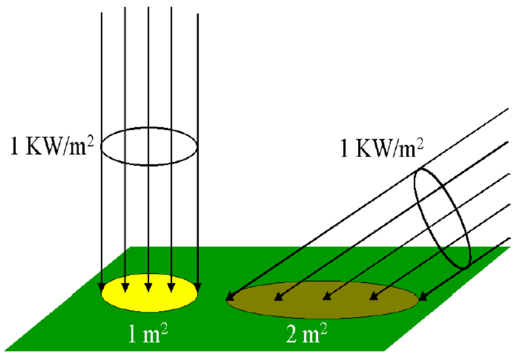
Air doesn't really "hold" moisture, but it sort of appears to. Basically, water evaporation is dependent on amount of energy, more energy = more evaporation. Therefore warmer air will generally have more evaporated water around it because warm air has more energy, so causes more evaporation of moisture at the surface. Hence why thermals result in cumulus clouds despite it being blue elsewhere at the same altitude.



Insolation

4

- Solar energy per unit area received at the surface of the Earth
- Air isn't heated much by the sun directly
- The surface of the Earth is heated by Radiation, which in turn heats the air near the surface by Conduction
- This heated air rises by Convection



Insolation

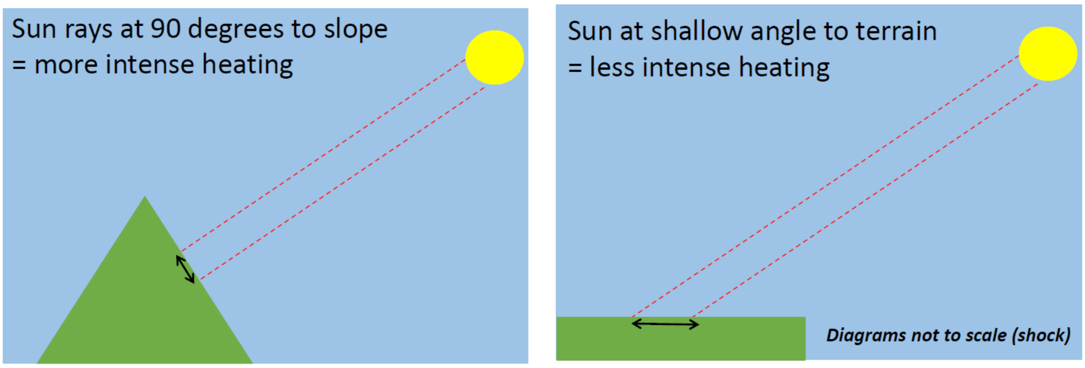
Insolation is defined as the thermal radiation received from the Sun per unit surface area of the Earth

Air is nearly transparent, and not significantly heated by the Sun

The surface of the Earth is heated by the Sun, which in turn heats the air in contact of the surface
Warm air near the surfaces rises by Convection.
http://zebu.uoregon.edu/disted/ph162/l4.html

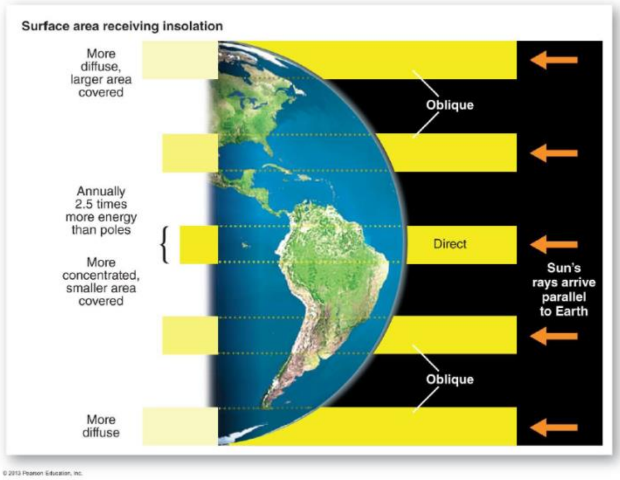
Insolation – Terrain

4



In Northern Hemisphere mountain areas, this is why East slopes tend to work early, South slopes during the middle of the day and West slopes in latter part of day **(simplification!)**

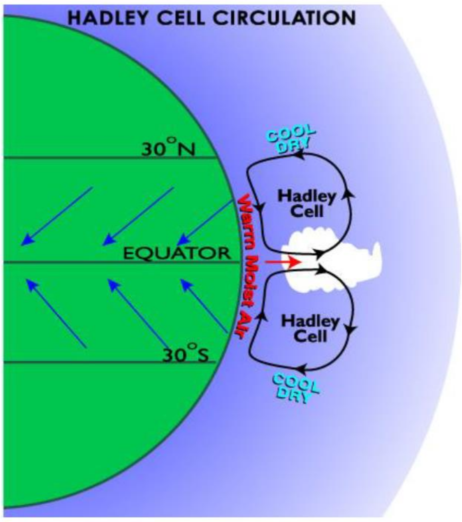
World Air Circulation



Additionally, the suns rays have to travel through more atmosphere nearer the poles.

Greatest Heating occurs at Equator (approx.)…

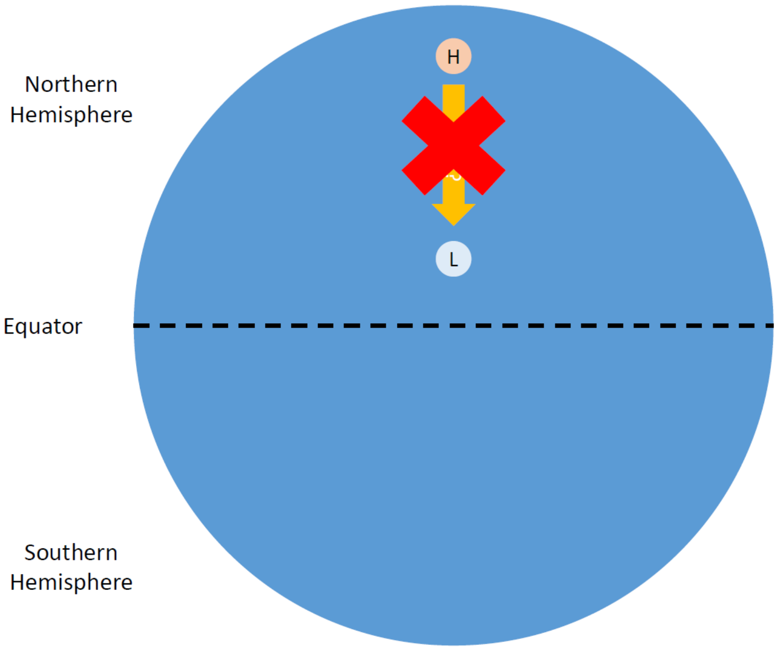
World Air Circulation



This causes the air to rise and in turn to draw in new air to replace that which has risen.

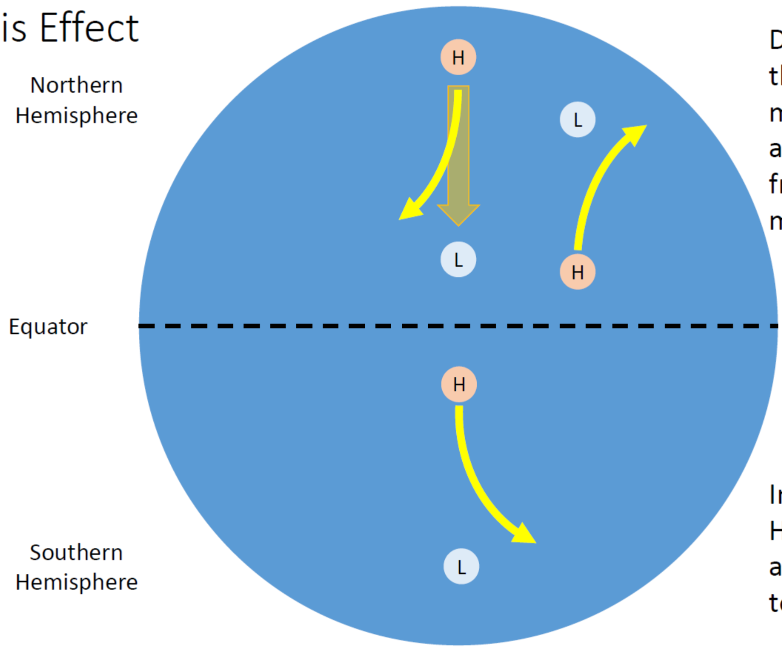
This rising air cools to the temperature of its' surroundings. Stops rising and spreads out North and South to about 30 Degrees of Latitude.

This is known as the Hadley Cell. There are two more cells per hemisphere to the north and south



We know air flows from High to Low Pressure, but on a spinning globe it's not quite as simple as straight lines...

Coriolis Effect



Due to the rotation of the Earth, any freely moving object or fluid appears to turn right from the direction of motion

In Southern Hemisphere, the appeared deflection is to the left.

Coriolis Effect

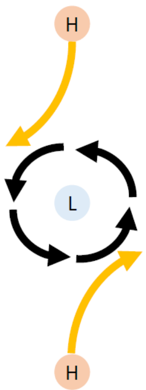
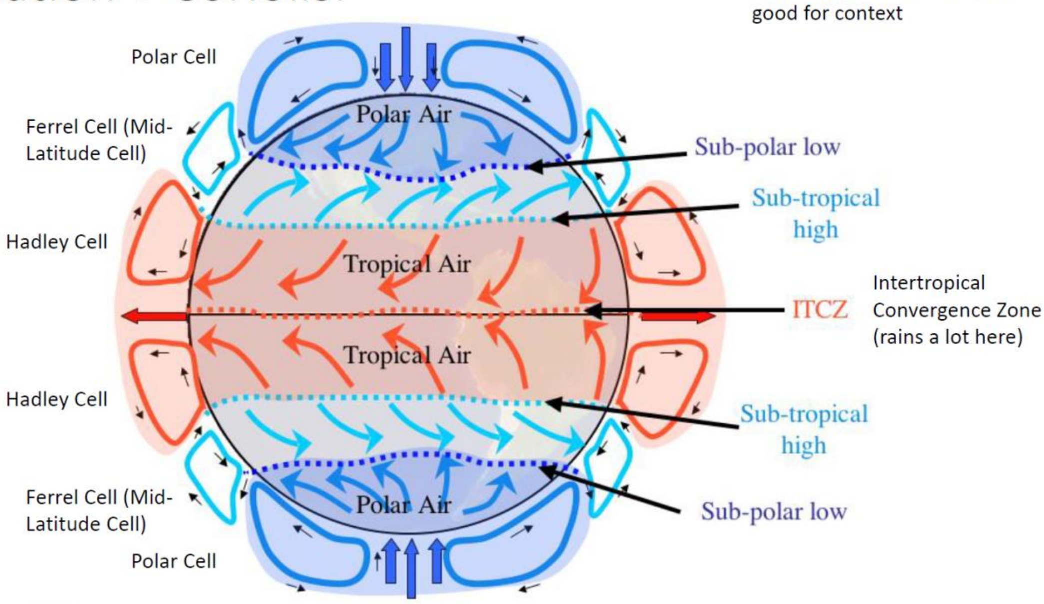


Diagram = Northern Hemisphere

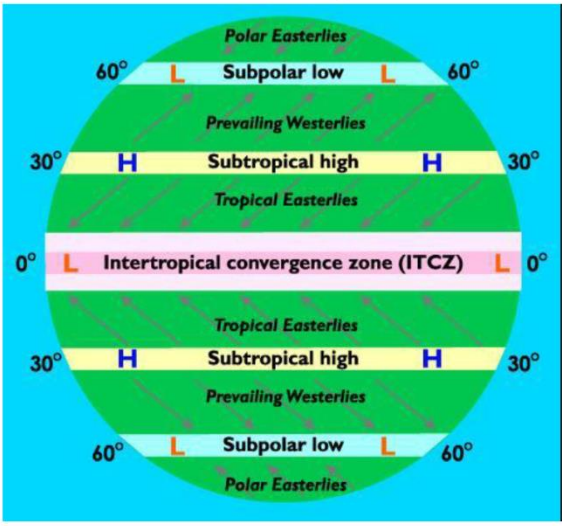
- Air flows toward an area of low pressure but the Coriolis effect deflects the air
- An equilibrium is established with a circular flow
- Direction is Anticlockwise around Low, Clockwise around High. Opposite direction in Southern Hemisphere
- The Coriolis effect is zero at the equator and greatest at the poles. Therefore, cyclones rarely form at the equator or travel towards it.

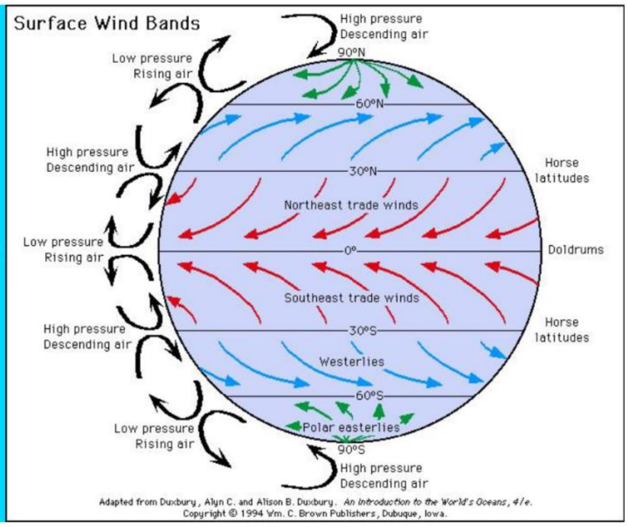
Circulation + Coriolis.

Apparently not on exam, but good for context



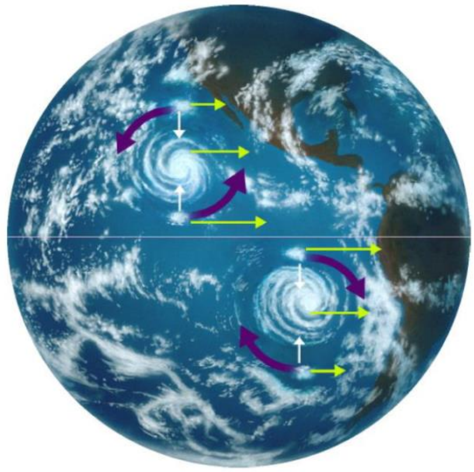
Alternative Diagrams





Pressure Systems

- Uneven solar heating plus the Coriolis means we get turning air masses
- Known as Pressure Systems



Actual photo of three storms over the Atlantic

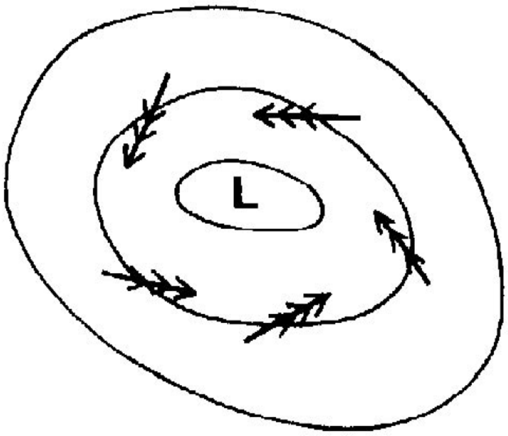
Pressure Systems
Hurricane Florence, Tropical Storm Isaac and Hurricane Helene swirl in the Atlantic Ocean in this image captured by the GOES-East weather satellite on Sept. 11, 2018, at 11:45 a.m. EDT (1545 GMT). (Image credit: NOAA/GOES-East)
https://www.space.com/41790-4-powerful-storms-seen-from-space.html

Pressure Systems – terms you must know for exam!

- Low Pressure System called "Cyclone" (Depression/Storm)
- High Pressure System called "Anti-Cyclone"
- Isobar = A line of constant pressure
- Isobar commonly 4 millibar apart (labelled on synoptic chart)
- 1 millibar pressure = 30 feet change in height
- Geostrophic Wind - Flow approximately in line with isobars (theoretical)
- Airmass = A large body of air within which horizontal changes in pressure, temperature and humidity are small
- Backing – wind changes direction **Anti-Clockwise (left)**
- Veering – wind changes direction **Clockwise (right)**

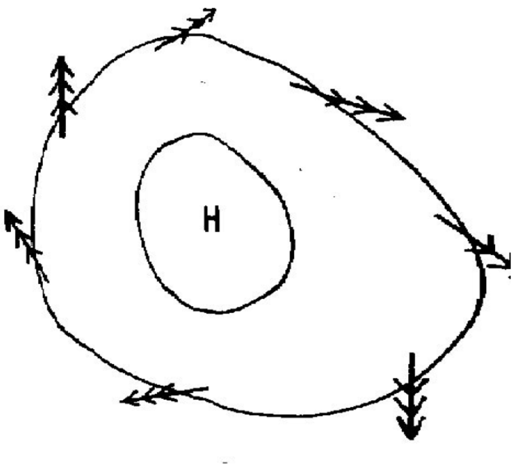
Pressure Systems terms
Geostrophic winds assume perfect balance between Coriolis and pressure gradient. Friction from ground usually means observed winds are not geostrophic (see next slides!)
I remember antic clockwise as time going **Back**wards, so that's backing.

Low Pressure (Cyclone)



- Ascending Air
- Anti-Clockwise Flow (**NH**)
- Below 1500 feet friction pulls the wind into the low
- Usually poor weather, fronts, cloud and rain!
- Pressure system characteristics may be on exam

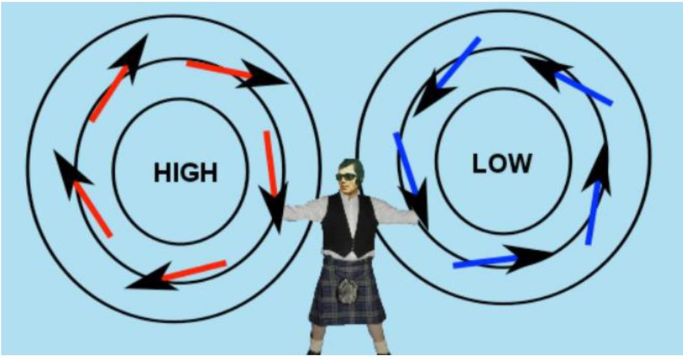
High Pressure (Anti-Cyclone)



- Descending Air
- Clockwise Flow (**NH**)
- Below 1500 feet friction pushes the wind away from the high
- Summer: Usually good weather, sunny and warm
- Winter: Often clear skies, but can bring fog / low cloud

Stupid “Law” that isn’t a law but you need to know it anyway for exam

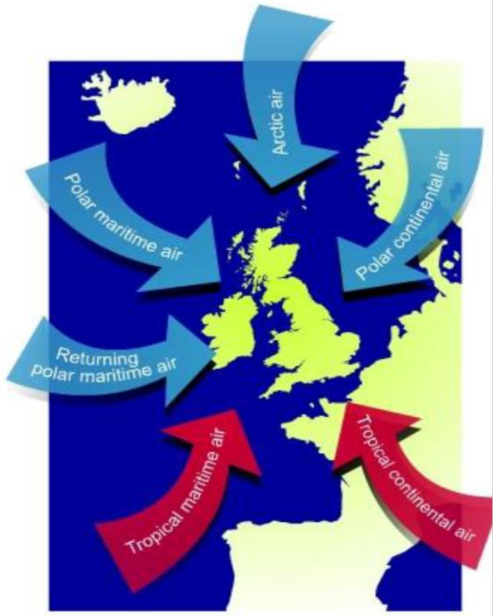
- <u>Buys Ballot’s Law</u> - In the northern hemisphere if you stand with your back to the wind the low pressure will be on your left.
- Only works with Meteo wind (e.g. Sea Breezes and Valley Winds can make this wrong). But a decent memory trick for wind around pressure systems when looking at a chart. Apparently sailors can use it as a very general guide to avoid large storms/hurricanes.

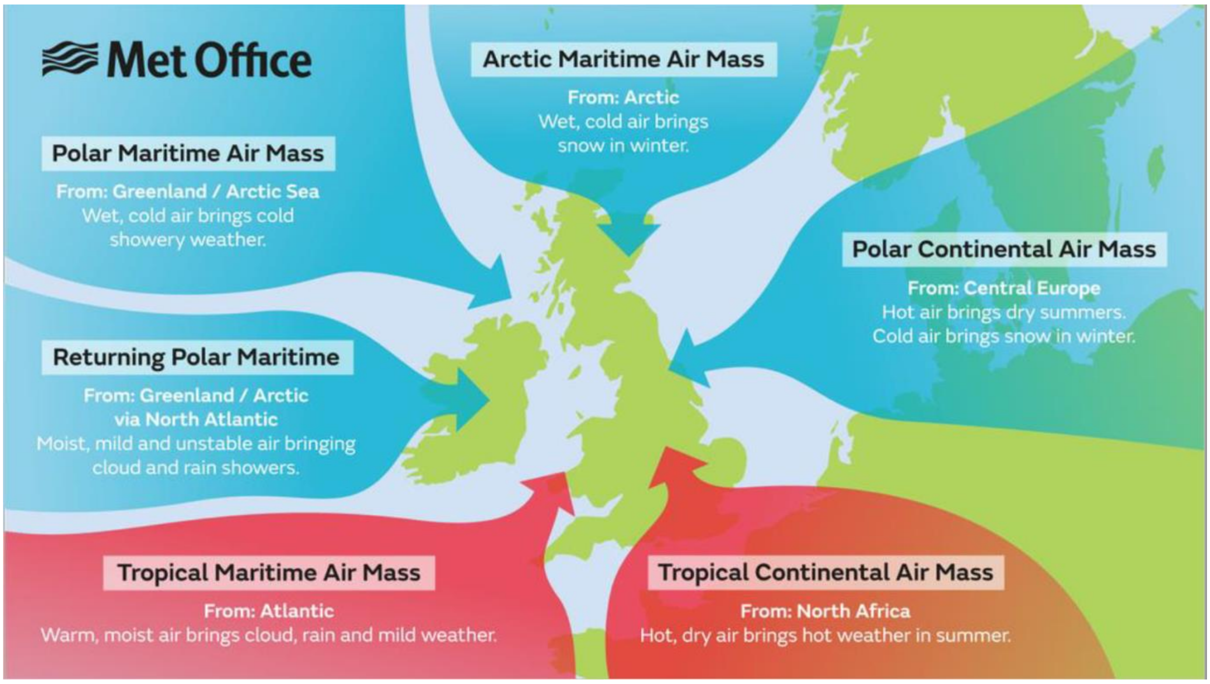


You may be able to sense some irritability in my slide preparation by past me, but you do need to know this for the exam, and it is useful for working out wind directions from synoptic charts – best regards, present me.

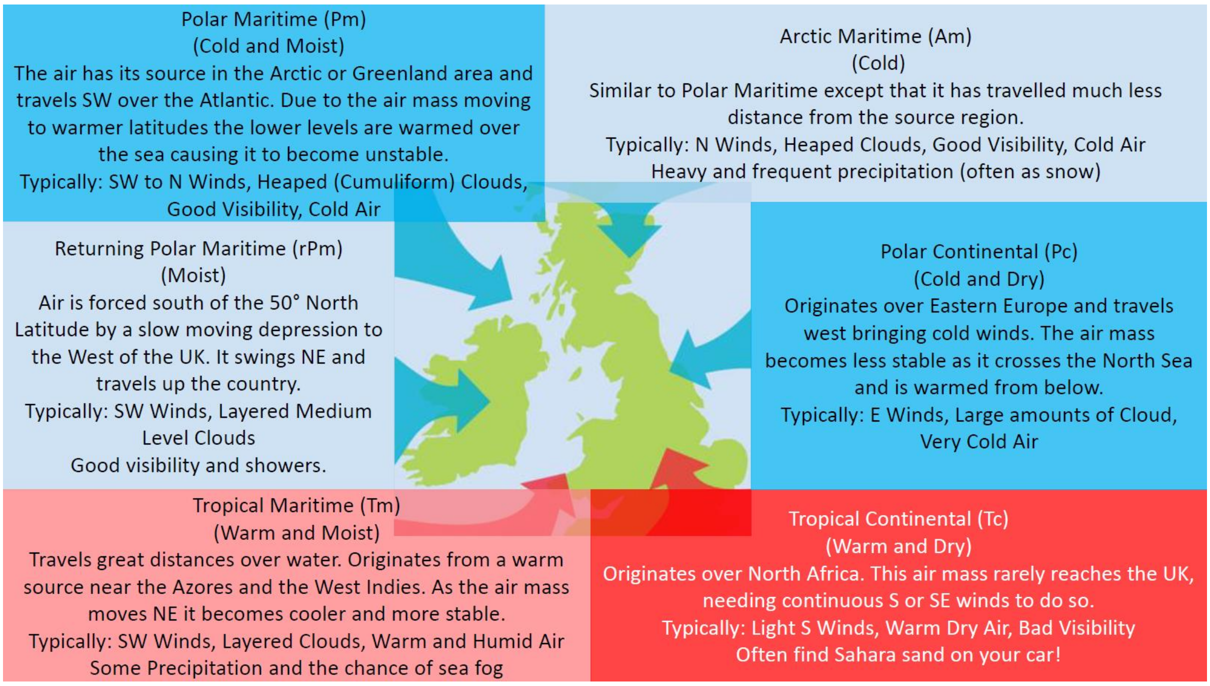
Air Masses

- The Characteristics of an air mass depends on where the air mass has come from
- Colder if they come from north or east
- Warmer if they come from south
- Pick up moisture over the sea
- Continental – originated over land
- Maritime – originate over sea





Google "Met Office Air Masses" for some useful info

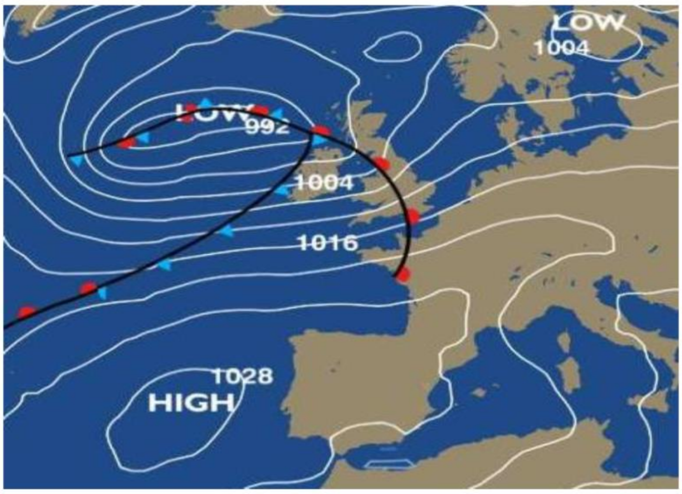


That's a lot of words, have fun learning this!

	Tropical Continental (Tc)		Polar Continental (Pc)		Tropical Maritime (Tm)		Polar Maritime (Pm)	Arctic Maritime (Am)	Returning Polar Maritime (rPm)
	Summer	Winter	Long Sea Track	Short Sea Track	Exposed	Sheltered			
Temp	Very warm or hot	Average	Cold	Very cold	Near sea temp	Warm	Rather cold	Cold (colder than Pm)	Warm (warmer than Pm)
Humidity	Relatively dry	Rather moist	Moist in lowest layers	Very dry	Very moist	Moist	Moist	Fairly moist (less than Pm)	Fairly moist (less than Pm)
Change of Lapse Rate	Little change	Cooled from below	Heated from below	Little change	Cooled from below	Warmed in summer	Heated from below	Heated from below	Heated from below
Stability	Generally stable	Stable	Unstable	Stable	Stable	Stable aloft	Unstable	Unstable	Unstable
Weather	Clear, occasional thundery showers	Clear	Rain or snow showers	Clear	Low cloud, drizzle	Broken cloud, dry	Variable cloud, showers	Showers (mainly coastal)	Showers (mainly coastal)
Visibility	Moderate or poor	Moderat e or poor	Good	Moderate or poor	Often poor with coastal fog	Moderate	Good	Very good	Very good

Fronts

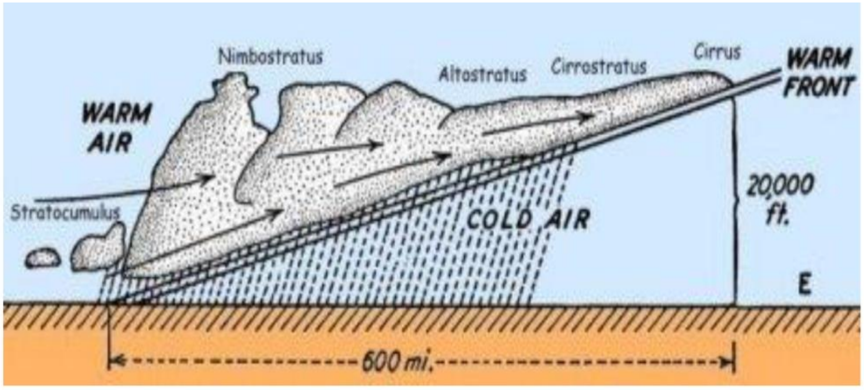
- A boundary between two different air masses
- Commonly found in depressions



Quite a classic example of a warm front, that is followed by a cold front, and an occlusion has formed where the cold front caught up to the warm front.

Warm Front

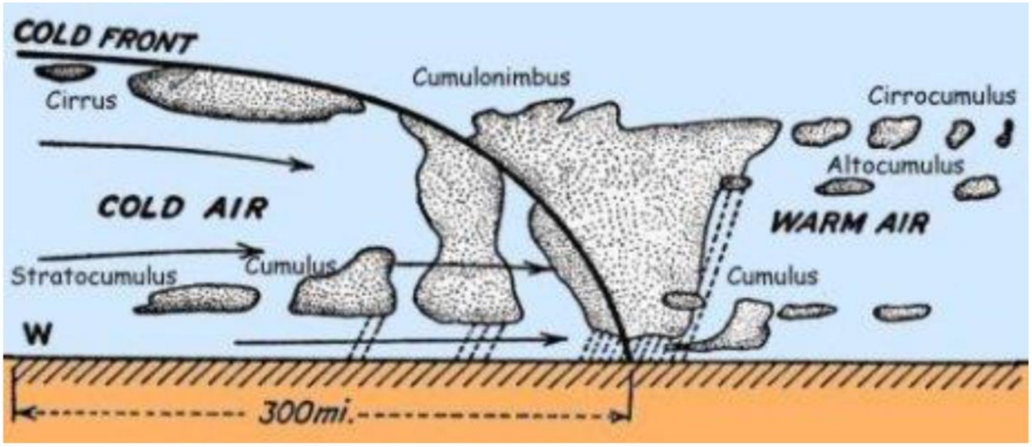
- An area of warm air catches up with an area of cold air and overrides it (due to the lower density)
- Shallow slope (1:50 to 1:400) with the air rising gradually over many hundreds of miles
- Gradually thickening layer of cloud eventually producing steady rain near the frontal zone.
- Slow Moving



- Frontal zone may extend 600 miles ahead of the transition
- High cloud such as Cirrus and Cirro stratus will shut off the solar activity
- Cloudbase will lower with Altostratus and Nimbostratus giving drizzle as the front nears.
- Rain may begin up to 5-10 hrs before the passage of the front.
- The winds may strengthen and back. At the front, the rain eases off, the wind will veer 50° or so and the temperature and humidity will rise. We are now in the warm sector.

Cold Front

- An area of colder air undercuts warmer air
- Steeper slope (1:10 to 1:100) with strong updraughts being produced
- May have rapid development of heavy showers
- Fast Moving (≈20mph)



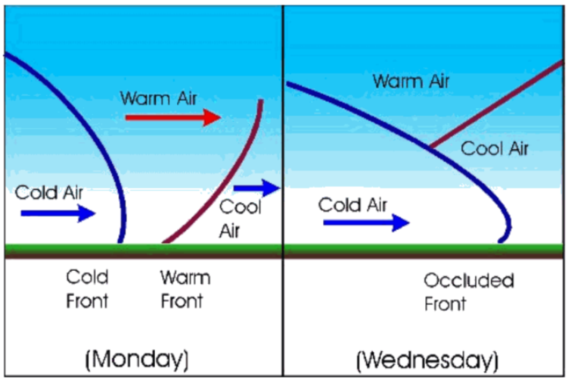
- The frontal zone effect may extend 100 miles ahead of the front itself.
- At the front, the temperature drops and the wind veers, often to the North West direction.
- Cumulus and CumuloNimbus may develop, with heavy rain.
- Behind the cold front, there is often a complete clearance of cloud but this very quickly gives way to high Cumulus.

Lots of good cross country days are post cold front

Occluded Front

- Cold fronts are fast moving, warm fronts are slow moving
- Cold fronts can catch up with a warm front and create an "Occluded Front"
- The weather is a mix of cold and warm front, usually on a milder scale

Occluded front – cross-section



Cold Front 

- The leading edge of an advancing cold air mass
- Appears on a synoptic chart as a blue line with triangles
- Direction in which the triangles point is the direction in which the front is moving

Warm Front 

- The leading edge of an advancing warm air mass
- On a synoptic chart appears as a red line with semi-circles
- The semi-circles point the direction the front is moving

Occlusion (or occluded front) 

- Form when the cold front catches up with the warm front
- Lifting the warm air between the fronts into a narrow wedge
- Appears as a purple line with a combination of triangles and semi-circles.

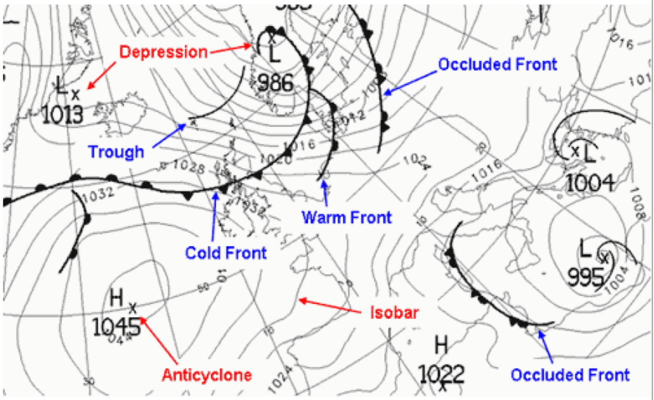
Troughs

- Region of relatively low atmospheric pressure
- Developing or old front
- Can bring area of more could and rain
- Don't think troughs are in the syllabus (but Cold, Warm & Occlusions are)

Important to nail down Cold, Warm and Occluded Fronts for exam

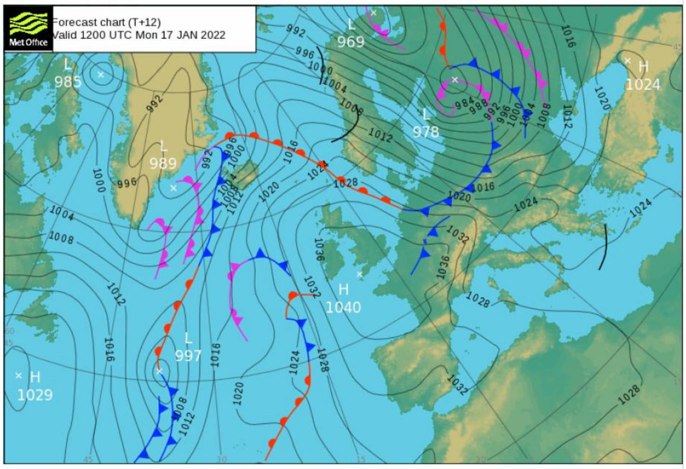
Synoptic charts

- Lots of information
- Show pressure systems, fronts, troughs, basically what we have been talking about.
- Wind speed by Isobar spacing (each space normally 4mb)
- 1 millibar = 1 hectopascal (hPa) – not sure of terminology on exam
- Very good for view of general and upcoming weather



Google "Synoptic Chart" to access, I use the Met Office website for them.

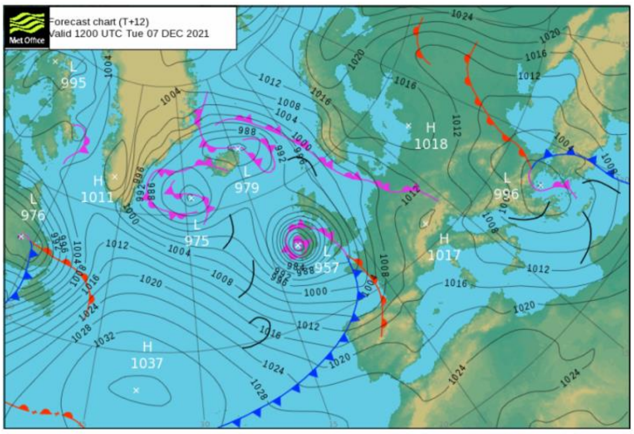
- Today!
- High Pressure
- Note only one isobar over UK – light winds
- Isobar direction at Lancs ties up with observed West/North West winds.



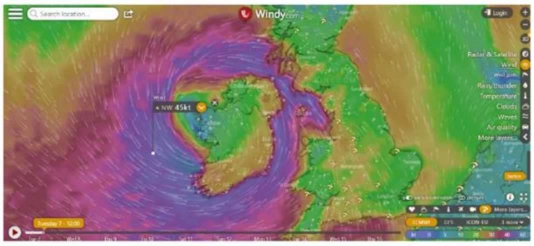
Today = 17th January 2022

Storm Barra 07/12/2021

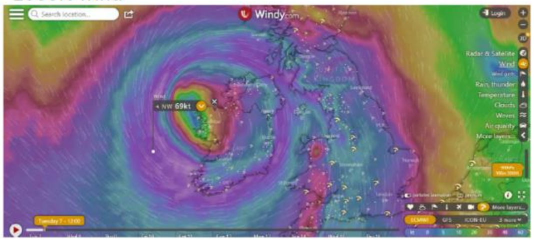
Direction of wind in Lancashire?



Surface wind



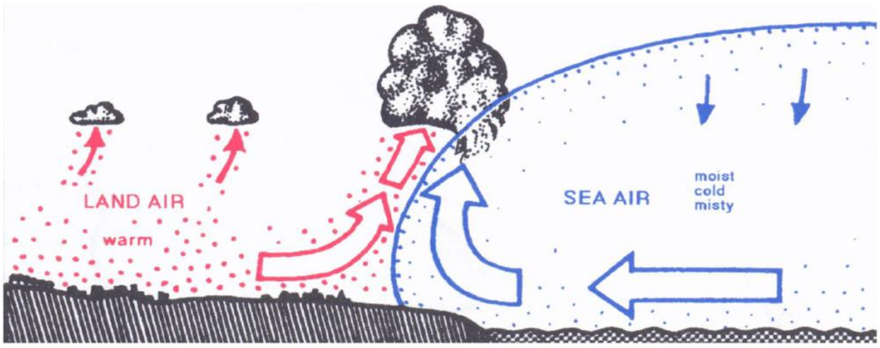
2000ft wind



Note very low pressure centred over Ireland and many very closely packed Isobars – windy!

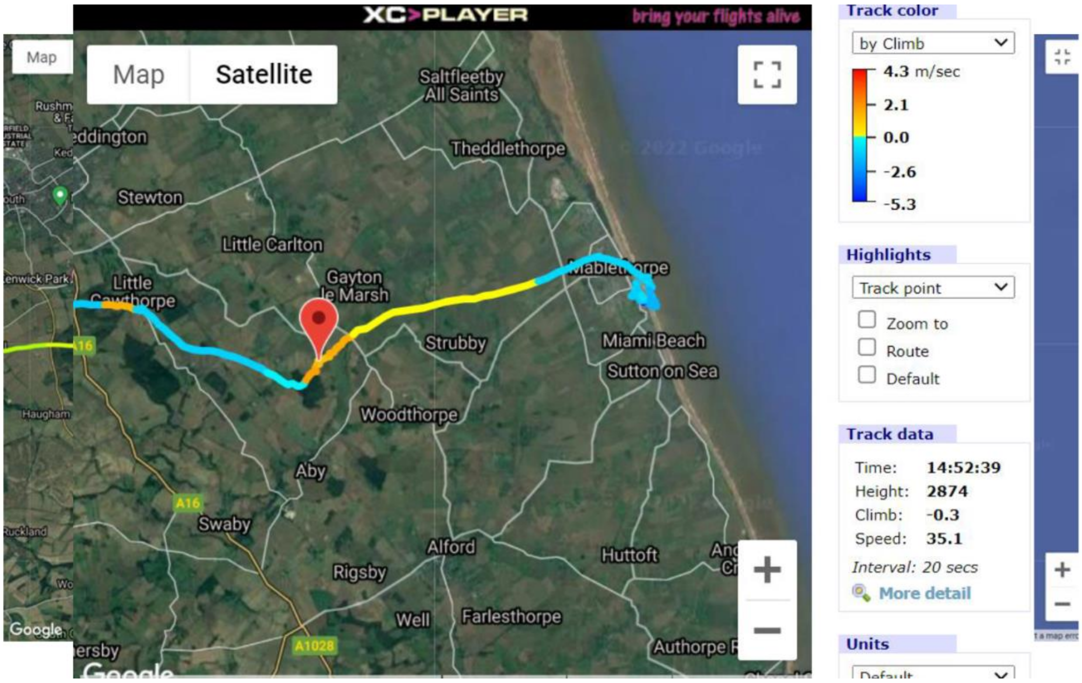
Sea Breeze Front

- Land warms up quickly but the sea remains at much the same temperature – air over land becomes warmer than air over sea.
- Thermal activity lowers the air pressure over the land causing air to flow in from the sea (to replace the lifting air).
- Sea breezes sometimes move many miles inland shutting off thermals near the coast.



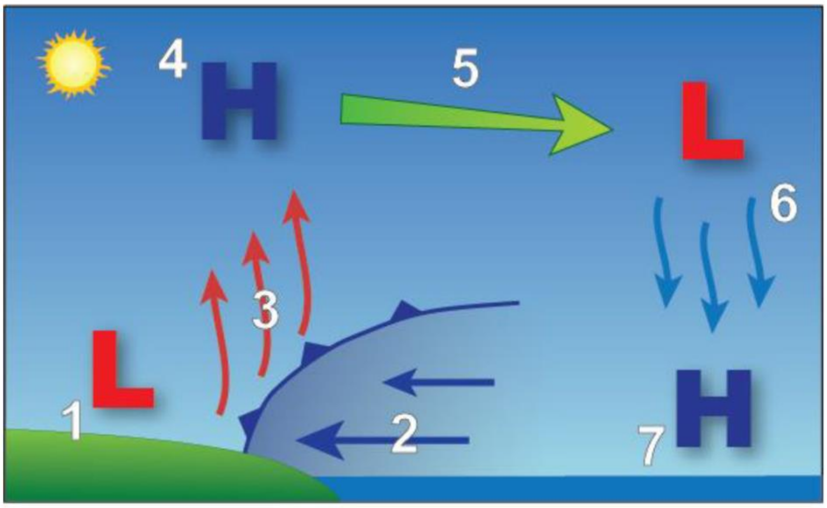
The large cloud in the middle formed by the rising air is usually referred to as "Sea Breeze Convergence". Convergence is just where winds in different directions meet and the air is forced to rise.

Over Mablethorpe in May 2021. Clear sea breeze convergence, and the wind direction changed by 180° when I dropped through the sea breeze front (and turbulence was evident).



Yellow part of the line shows the lift in the sea breeze convergence.

Alternative diagram



H/L refer to High and Low pressure.

Clouds - Formation

- Clouds form when air is cooled to a temperature at which it cannot "hold" moisture (dew point temperature).
- AKA air condensing

Typhoon included to show how air is condensed by being cooled – the aircraft generates a lot of lift during pitching manoeuvres, due to a low pressure area above the wing. This means the air is cooler here, and in the example picture the air has cooled to the dew point or colder and therefore has condensed. All you need to know for exam is air cooled to dew point = condensed air, i.e. clouds.
Other photo is flying fairsnape with especially low cloud in 2021.

Clouds - Convection

- Thermals, leading to cumulus clouds
- More on this in a few slides

We like these. Photo is flying towards Pen Y Fan

Clouds – Orographic Uplift

- When moving air is forced to rise by an obstruction
- Such as a mountain chain or hill, it will cool
- If it cools below its dew point, it will condense to form orographic cloud

- There are different types, but this is all you need to know for exam

Parlick does this quite a bit in winter

Clouds – Lenticular

- Lens shaped clouds indicate the presence of wave activity
- Form where the wave is highest and may 'stack'
- Look really cool, but take care if there are many around…

More Clouds

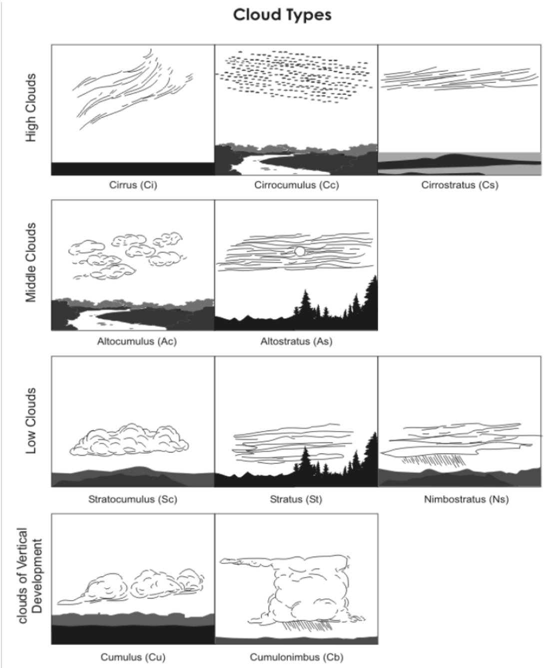
Turbulence and Mixing

- As air flows over the surface of the earth
- Frictional effects cause variations in local wind strengths
- Eddies are set up which cause the lower level air to mix
- The more friction, and the stronger the wind, the more mixing
- As the air mixes, it may rise and if it cools enough, **layer cloud** above the friction area may result.

Widespread lifting

- When two air-masses meet, as in a frontal system
- Large areas of warm air may flow over the cooler air and rise
- Producing large areas of cloud
- See section on Fronts

Google "boring clouds" to see these!

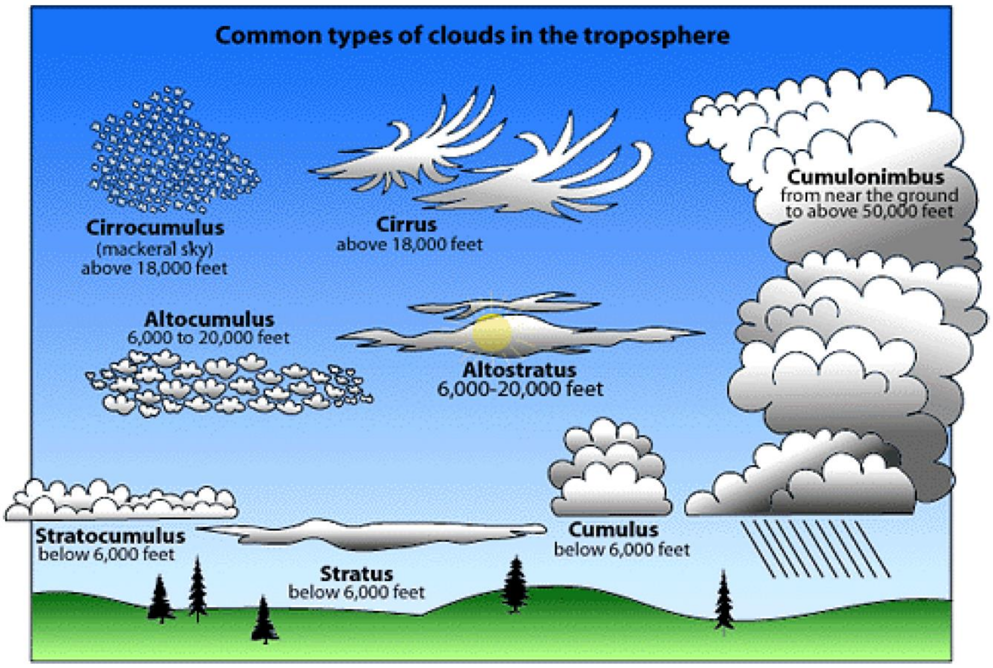


Cloud types

Clouds are classified by altitude, shape, and characteristics

- High Altitude = “Cirro” (15k-40kft)
- Mid Altitude = “Alto” (6k-23kft)
- Low Altitude = No Prefix (0 to 8kft)
- Cirrus - Hair-Like wisps, made up of Ice crystals
- Stratus – Featureless layers, made up of water droplets
- Cumulus – Heaped piles, made up of water droplets
- Nimbus – Raining!

Important for exam



Fog

Radiation Fog

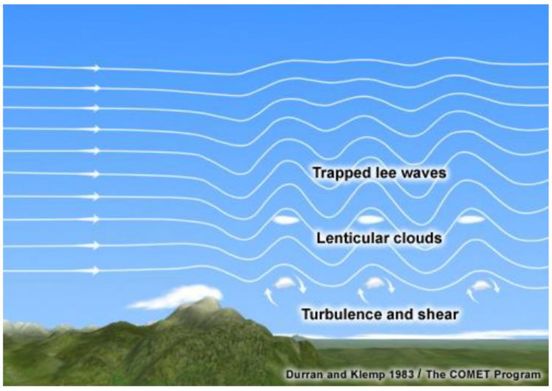
- On a clear night heat radiates away from the earth's surface
- Air in contact with the surface cools to the dew point
- Worsened by light winds which reduce mixing with warmer air higher up

Advection Fog

- Warm moist air mass flowing across a significantly colder surface (e.g. the sea)
- Will be cooled from below
- If its temperature is reduced to the dew point, then fog will form
- One example is sea fog

Wave (info from Met Office)

- Standing waves can form in the lee of hills or mountains.
- Usually occur in stable air (thermals break up wave) when there is a temperature inversion above a hill/mountain (or with strong wind shear).
- With air flowing at roughly right angles to the barrier, as the air moves over the mountain, it is forced upwards. When the air encounters the inversion, it is then deflected downwards.
- As the air is stable, it tries to return to its original level, so an oscillation is set up.
- This oscillating motion can bring stronger winds higher up in the atmosphere down to the surface, giving strong lee slope winds.

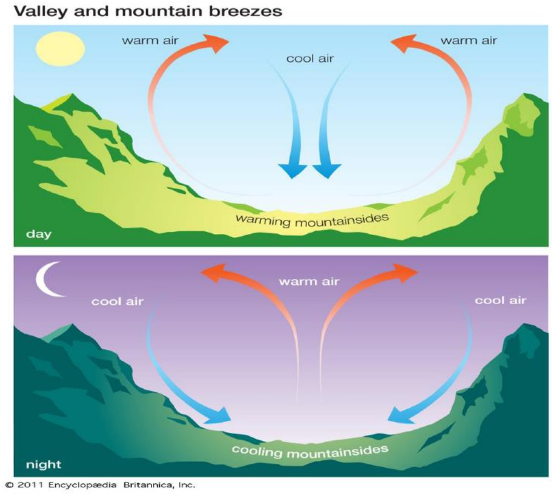


Gliders (AKA sailplanes) can get incredible altitudes in big wave. Hang gliders can too, paragliders can use wave but not qute to the same extent due to low airspeed.

Anabatic/Katabatic Flow in Mountains and Valleys

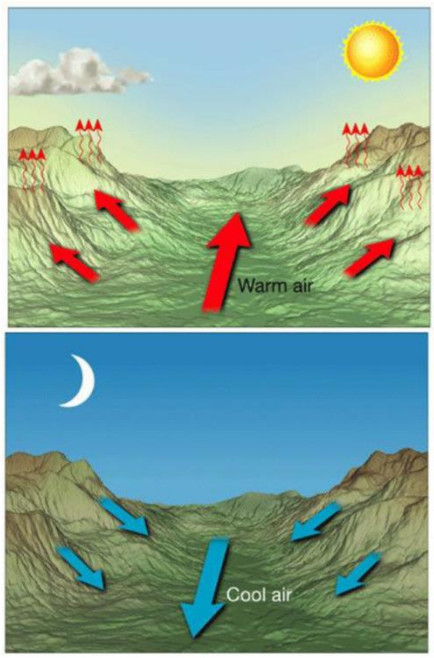
- Anabatic – during day
- Wind flow upslope due to mountain heating
- Weather needs to be fairly calm with sunshine

- Katabatic – at night
- Wind is downslope
- Occurs once ground heating is insufficient
- Magic Lift can occur in valley



Valley winds

- Anabatic winds in high mountains creates low pressure area in valleys
- (i.e. the air that has risen needs to be replaced)
- Air from the plains therefore flows into valleys
- Known as valley winds
- Generally upslope during anabatic, downslope during katabatic
- Anabatic – reverse of streams, mostly
- Must know about this when flying big mountain regions – **ask locals**

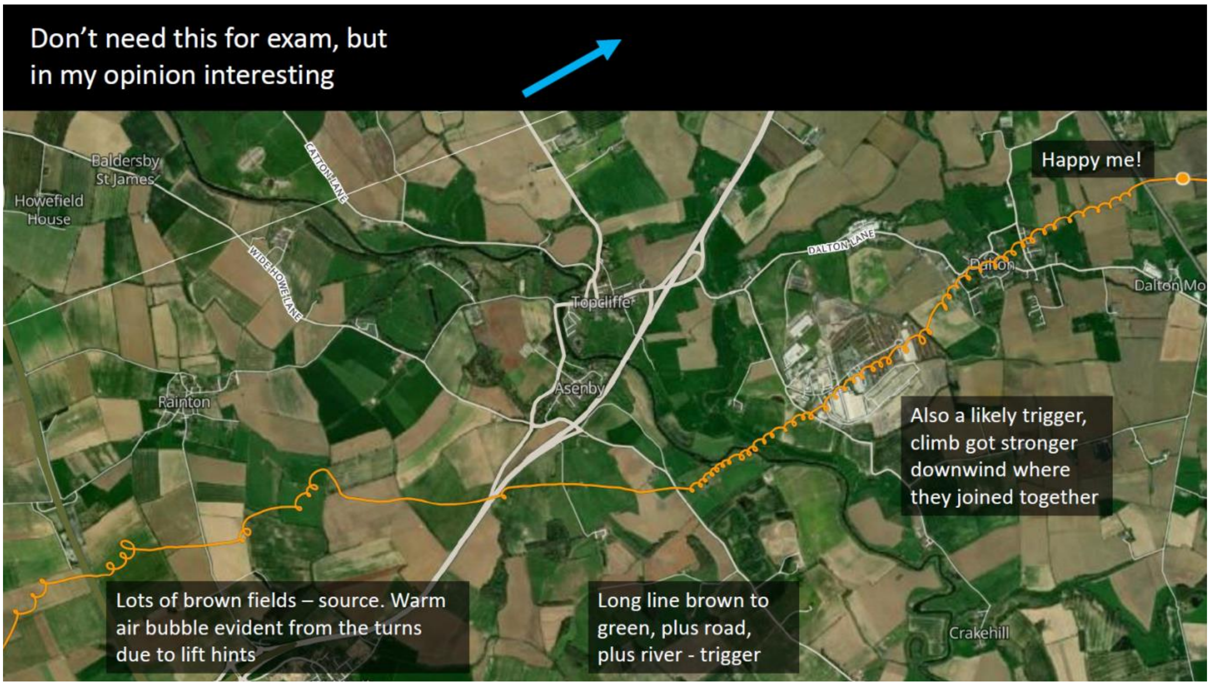


2 previous slides vital to know when flying the Alps, or any large mountain area (Scotland too). The Lakes/Snowdonia are more attributed with sea breeze phenomena, ask locals if in doubt!

Convection – Thermal Growth and Activity

- The sun heats the ground (Insolation)
- The ground heats a layer of air above
- This forms a bubble of warm air, which is warmer and therefore less dense than the surrounding air (source)
- If it unsticks, the warm air bubble will rise (trigger)
- As the density and the pressure of the surrounding air decreases with altitude, the thermal will expand adiabatically and hence it cools
- The thermal will cool at a known rate and its rate of cooling or lapse rate is the “Dry Adiabatic Lapse Rate” or DALR
- “Dry” refers to the moisture in the thermal being retained as vapour and not condensing (i.e. prior to cloud formation)

Source/trigger might not be necessary for exam, but good thing to know if you are interested in thermal flying.



From near topcliffe, in a flight from Parlick.

Things to know

- Dew Point = Temperature at which moisture condenses out of the air
- Bradbury Rule: Cloudbase (ft) = (Air temp - dew point) x 400 (approx.)
  Example: 22° air temp, 12° dew point: (22-12)x 400 = 4000 ft
- Lapse Rate = Change in temperature with height
- Adiabatic = A process where no heat energy is gained or lost from the surroundings

More Things to know (sorry)

- Environmental lapse rate (ELR) = 2°C/1000ft

Reality check – this is very assumption based

- Dry adiabatic lapse rate (DALR) = 3°C / 1000ft
  - Thermals cool at this rate prior to cloud formation
- Saturated adiabatic lapse rate (SALR) ≈ 1.5°C/1000ft
  - Condensed air cools at this rate – cloud suck
- Inversion = Area of the atmosphere where temp rises with height
- Isothermal = Area of the atmosphere where temp is stable with height
- Stable = ELR < DALR   Unstable = ELR > DALR

More things to know (sorry)
Condensed air is less stable because the act of condensation releases latent heat, warming the air, causing it to retain more heat than dry air and keep rising more readily.

Standard ELR (2°C/1000ft) on a graph

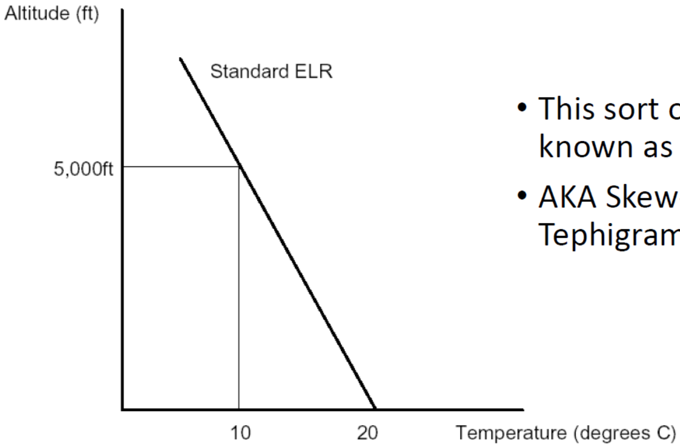


Figure 12 Standard ELR

- This sort of graph is known as a sounding
- AKA Skew-T, Tephigram

Real ELRs are a lot more wiggly (soundings can be viewed on RASP if you're interested, but more complicated than what is needed for exam)

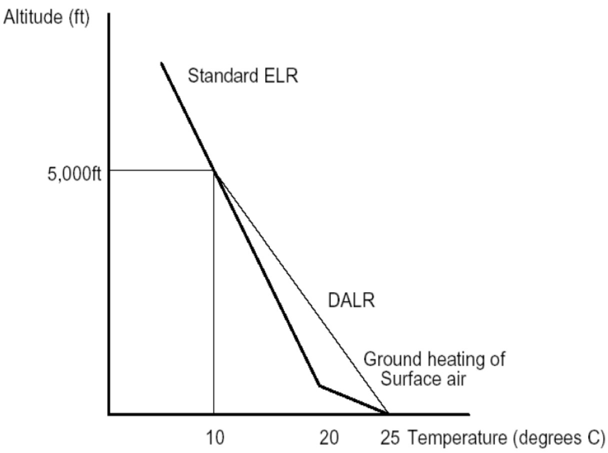


Figure 13 ELR and DALR

- A thermal leaves the ground with a temperature of 25°C
- The thermal "pocket of air" cools at the DALR
- At 5,000ft the thermal has cooled to 10°C and reached equilibrium with the surrounding air and stops rising.
- No clouds here ("blue")

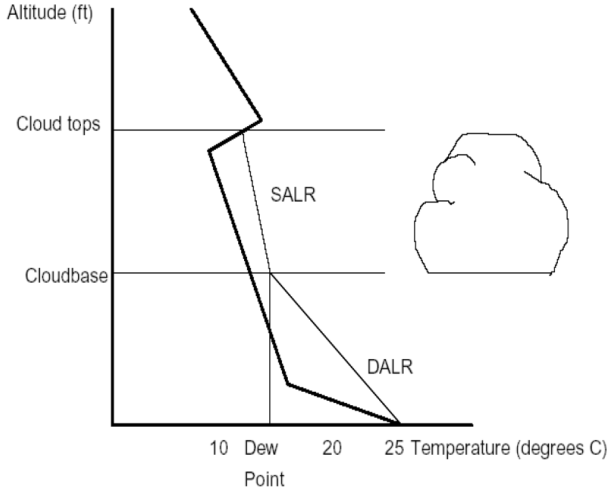


Figure 15 Convective cloud formation

- Example with clouds
- Thermal cools at DALR until it reaches dew point temperature
- Condensed air cools at SALR, continues to rise
- When cloud air reaches ELR at the inversion, air stops rising and that is the cloud top
- Cloud tops can also occur when air runs out of moisture
- SALR is steeper – very unstable

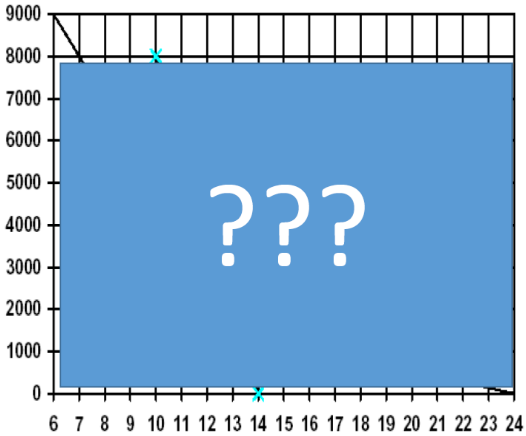
Height	Air temperature
0	24
1000	17
2000	15
3000	13
4000	11
5000	9
6000	7
7000	8
8000	7
9000	6

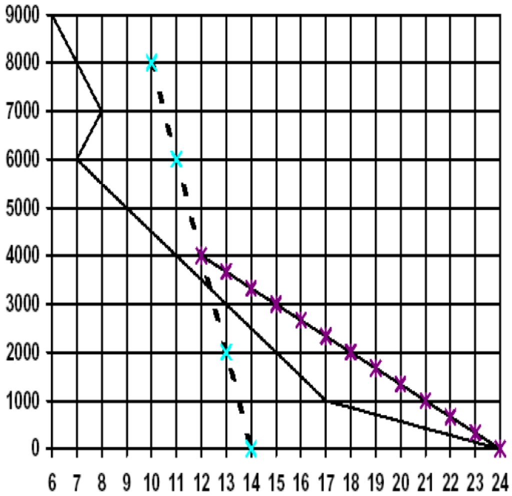
Example Question

- Soundings of air temperature at different heights above the ground have been taken and plotted.
- The dew point at ground level is 14C.
- Plot the course of a thermal releasing from the ground at 24C.
- Note: dew point in this answer decreases at 0.5°C per 1,000ft (need to check!)

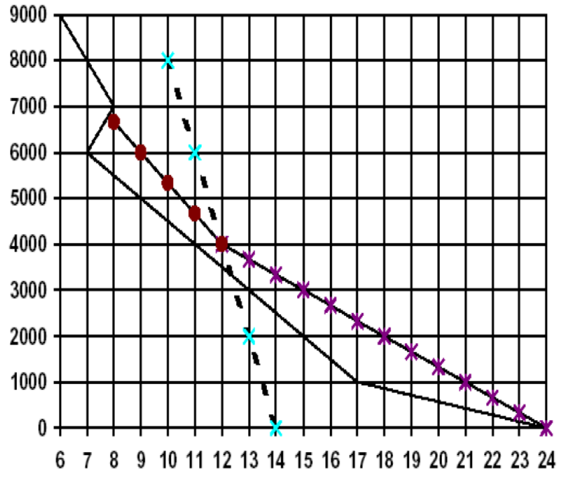
For the exam, as long as you know that clouds will form when the ELR meets the Dew Point, then that is sufficient.

Height	Air temperature
0	24
1000	17
2000	15
3000	13
4000	11
5000	9
6000	7
7000	8
8000	7
9000	6





The thermal leaves the ground with a temp of 24°C and rises at the DALR. 3°C per 1000ft



Then rises at SALR (1.5°C per 1000ft)

The SALR hits the inversion at about 6,600ft.

Cloud tops are limited by the inversion to about 6,600ft.

Cloud base is 4,000ft

Probably something like this on the exam – you need to understand all this

Forecasts (there are hundreds these days…)

- RASP, especially for cross country flying
- Windy (including different models, such as ECMWF, GFS, ICON)
- XCWeather (XCWeather Wind Observation map is good)
- Met Office, Mountain forecasts useful
- Flybubble weather (uses RASP data, “flyable hill” indication but can be iffy!)
- TV, radio, phone an airfield…
- CAVOK - “Ceiling And Visibility Okay” Visibility 10km or more, no cloud below 5000ft above aerodrome elevation and no cumulonimbus cloud at any level. No significant weather at or in the vicinity of the aerodrome.

No Forecast is Gospel – observation & interpretation is king

Learn the CAVOK thing! Used in METARs, which are weather reports from airfields. TAFs are forecasts. More info can be found via Monsieur Google.

Important things not on exam

- Wind gradient – especially in winter
- Wind and terrain interaction (venturi)
- Foehn, in the Alps/large mountain ranges, plus other named winds (always check local area)
- Gust fronts

Also convergence isn’t really mentioned except possibly sea breeze convergence. Can be a very powerful tool when flying in the UK, or anywhere.

For further info…

- Pilot exam notes - https://www.dhpc.org.uk/coaching/rating-exam-revision-materials
- BHPA Handbook
- Youtube DSC Meteorology talk by Mike Miller for pilot exam
  - Part 1: https://youtu.be/zliNo2E1UCU
  - Part 2: https://youtu.be/nJ_zhQJfKa8
- Met Office website “Learn About” https://www.metoffice.gov.uk/weather/learn-about/weather
- Understanding Weather – very good book
- Thermal Flying – very good for cross country flying
- Feel free to whatsapp/telegram/e-mail me, or put on coaching group!

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New years eve 2020, Parlick, TTB in the last light of the year. Inversion evident. Did a TTB launching in thick snow to get down before the landing field got fogged up! Extremely cold.

There has been interest in use of RASP Custom Soundings, so here is some info, but don't bother looking for the pilot exam as it's not helpful for it. I might do a talk on this if anyone wants to be bored to sleep!

Skew-T ("Skewed Tephigram")

- Imagine a weather balloon floating up high and recording temperature, dew point temperature, wind strength and direction and moisture content in the air
- This is the resulting graph

- Weather balloons still used, but satellites with passive and active sensors can also generate soundings

- The custom soundings in RASP are a **Forecast**