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Chapter 1

Atmosphere

. **Mixture of gases** → ① Nitrogen 78% ② oxygen 21% ③ other gases 1%

. air pressure = . decrease with increase altitude
. directly proportional to air density

. Ozone ⇒ absorbing short-wave solar radiation ⇒ act as heat source

Structure of atmosphere

. use temperature lapse rate to identify its different layers

Troposhere (lowest layer)

. temperature decrease with height ⇒ 2°C / 1000 ft - 0.65°C / 100 m

. contained water vapour

. weather

Tropopause

((16 × cos lat) × 3280) → boundary

. air is stable = temperature doesn't decrease with altitude ⇒ . highest altitude tropopause = lower temp
. lowest altitude tropopause = warmer temp

. height ⇒ determined by temperature of the air near the surface → varying due to latitude - season - type of surface
. over equator = high tropopause - over poles = low tropopause

. tropopause breaks = due to large surface temperature changes over a short distance = abrupt change in height

Stratosphere

. temperature change isn't uniform ⇒ . **Lowest layer** → temp is more or less constant
. **Altitude increase** → temp increase / caused by ozone layer (short wave radiation interacts with oxygen)

. no active weather - no convective turbulence

Mesophere

. temperature decrease with height

Thermosphere

. temperature increase with height

Isa deviation

. comparing actual atmospheric conditions - ISA condition

+ → warmer than ISA / − ⇒ colder than ISA

Chapter 2

Temperature

. air is poor conductor of heat

Heat energy associated with the movement and collision of molecules

Temperature scale

1. **Celsius** ⇒ . 0°c = freezing point - 100°c = boiling water
. liquid water can form below 0°c

2. **Fahrenheit** = . freezing - boiling = 32°F – 212°F

3. **Kelvin** = . no energy = no heat ⇒ absolute zero = -273°c

. Celsius to kelvin = K = c° + 273

. Thermometer is located 4ft above ground

. Radiation = . temp of body > absolute zero ⇒ emits energy in the form electromagnetic

. Absorption = receive radiation = heat up

. Specific Heat Capacity = . amount of energy required to change temperature

. Water = longer to warm up - cool down | . Land = take little time to warm up - cool down

sophia

Solar Radiation

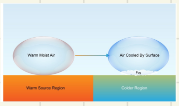
. most of the energy from the sun is short wavelength

. 85% reach the surface / 15% absorbed by ozone

. Insolation ⇒ . some is reflected by Earth's surface
. some is absorbed by surface = warm up the surface

. ADVECTION: . horizontal transfer of heat

• caused by convection over the land and sea ⇒ wind blowing



Terrestrial radiation . release by earth's surface (long wavelength)
. directly heats our atmosphere (higher level)

CONDUCTION: . transfer of heat by direct physical contact / predominantly at lower level

• At the night cooled the air close to the surface by conduction
• During the day the warm surface temperature has warmed the air near the surface

→ conduction layer

CONVECTION: vertical transfer of heat / vertical movement of air, both up and down / predominat at higher level

• WARMER SURFACE → less dens → lighter than the surrounding → pocket of warmer air rises

• COOLER SURFACE → density will increase → air will sink

Latent heat

. energy released - absorbed without change its temperature

Latent heat release	Latent heat absorbed
. condensation = gas to liquid	. evaporation = liquid to vapour
. sublimation = . directly from gas to ice . without water droplets being formed	

Sun's radiation →

. at the poles = . low angle sun's radiation ⇒ wide area = cooler than equator

. at equator ⇒ . high angle sun's radiation = small area . hotter than poles

. surface temperature decreases with increase in latitude

. Perihelion → Earth closest to the sun (early January)

. Aphelion → Earth farthest from the sun (early July)

. Thermal equator → latitude receiving maximum insolation

. Equinoxes → length of day = length of night

During the day, when a cloud layer is present, it reflects a significant portion of the incoming solar radiation back into space. This reflection prevents a considerable amount of solar energy from reaching the Earth's surface, resulting in cooler maximum surface temperatures compared to when the sky is clear.

At night, the situation changes. Clouds have the ability to absorb and trap thermal radiation, particularly infrared radiation, which is emitted by the Earth's surface. As the surface loses heat energy through radiation, the clouds absorb this infrared radiation. The absorbed energy is then re-radiated back towards the surface, effectively acting as a blanket or insulator.
This re-radiation of the absorbed infrared radiation by clouds helps to maintain warmer surface temperatures during the night compared to clear sky conditions.

Diurnal variation of surface air temperature:

① **During day** → . reach maximum at noon → highest point in the sky
. surface air temperature increase

② **During night** → . earth radiate energy = earth's surface cools

. water ⇒ diurnal variation less / land = large diurnal variation

. wind ⇒ . during day ⇒ mix cold temp (high level) - warm air (low level) = surface air temp decrease

. during night ⇒ mix warm air high level - cooler surface air = surface air temp slightly higher

Inversion

- increase temperature with height = stability of the air

① **Ground inversion** = . during night
- surface of earth cools the lowest layers of atmosphere = surface layer colder than higher level
- can be created by ⇒ warm air advected over a cooler surface

② **Subsidence inversions** : . air sinking over wide area = warm adiabatically
- air above surface is warmer than the air below it
- high pressure present

③ **Turbulence inversions** : . mixing of air ⟶ forced to move vertically
- few thousand feet above ground level

④ **Frontal inversions** : . boundaries between warm - cold air
- due to different densities ⇒ colder air slides under warm air

⑤ **Valley inversion** : . air cooled by the land = become denser ⇒ flow down
- air in the bottom is colder than the air above it

Chapter 3

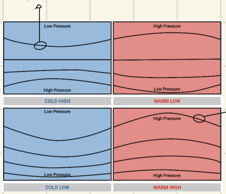
- **Atmospheric pressure** : pressure solely by the effect of gravity on a mass air
- 1 hpa = 1 mbar / height from pressure ⟶ $\frac{(96 \times \text{temp in kelvin})}{\text{hPa}}$
- greater the mass overlying air ⟶ greater atmospheric pressure
- **horizontal pressure variation** : a change in surface pressure
- **isobares** ⟶ lines of equal pressure (intervals 2-4 hpa)
- **Ridge** ⟶ extension of high pressure
- **Col** ⟶ between two high pressure and two low pressure = widely space
- **Trough** ⟶ extension of low pressure
- **flat** ⟶ low pressure with widely spaced isobare

Pressure gradient force : . force that tries to drive from high pressure to low pressure
- greater difference pressure ⟶ greater PGF

- **diurnal variation of pressure** : . variation depends by latitude
  - highest variation in the tropics / non-existent at the poles
- **vertical pressure variation** : . at the bottom of the atmosphere ⟶ decrease very quickly with height
  - upper atmosphere ⟶ pressure decrease slowly
  - in real atmosphere ⟶ rate of pressure change with height isn't fixed
- **effects of temperature** : ① Cold air : . more mass = denser ⟶ reduce distance between isobares
  - pressure falls more quickly

  ② warm air : . pressure change slowly height
  - expand isobare ⟶ pressure level upward

downward ⟶ low pressure



upward ⟶ high pressure

- cold high ⟶ weaken with increasing altitude
- warm high ⟶ increase with altitude

QFE ⟶ . barometric pressure at an aerodrome reference point
- when is set ⟶ read zero at aerodrome / in airborne: indicate height above aerodrome reference point

QNH ⟶ . QFE adjusted down to mean sea level using airfield's elevation
- using ISA pressure lapse rate - ISA temperature

Standard Pressure setting : . standard pressure ⟶ 1013.25 hpa
- height above 1013.25 ⟶ FLIGHT level

QFF ⟶ . calculated mean sea level
- take account the actual pressure change - actual temperature

1 Above sea level	② below sea level	③ sea level
. warm air : QFF < QNH	. warm air : QFF > QNH	. QFE = QNH = QFF
. cold air : QFF > QNH	. cold air : QFF < QNH	

Chapter 4

- density → mass of air within a specified volume
- ISA → 1.225 kg/m³ - 1225 g/m³
- FACTORS : ① Temperature → . Temperature increase → move around a lot more → density decrease
  - . Temperature decrease → density increase
  - ② Pressure → . increasing pressure → volume of air decrease = density increase
  - . decreasing pressure → volume of air increase : density decrease
  - ③ humidity → . how much water vapor is in the air
  - . increasing humidity → decrease density
  - . cold air : less hold water molecules → density decrease more quicker with altitude
  - . warm air : hold more water molecules → density decrease slower with altitude
- effect of temperature > effect humidity
- density decrease with altitude

Density altitude → pressure altitude corrected for temperature variation

International Standard atmosphere

- Temperature = +15°c
- pressure = 1013.25
- Temperature lapse rate = 0.65°c / 100m (2°/1000 ft)
- from to 11 km to 20 km = -56.5

Chapter 6

Altimetry

- aneroid barometer → change air pressure = metal capsule expand - contract
- change sub-scale setting = altimeter read will change → increase subscale = increase pressure

① height = . above ground level (QFE)

② altitude = above mean sea level (QNH)

QFE	QNH	QNE
. obtain height above airfield	. at rwy threshold = obtain elevation	. indicate height on 1013.25 hpa
. rounded down / varies with day	. calculated barometric pressure at MSL	
. show zero feet at threshold	. rounded down	

Regional QNH → . lowest forecast QNH within region

. use for cross - country / flight below TA

Horizontal variation pressure

. From high pressure to low pressure ⇒ . True altitude decrease

. indicated altitude remain the same

. from low pressure to high pressure → . True altitude increase

. lower pressure area = over read = warmer than ISA

. high pressure area = under read = lower than ISA

. Transition altitude : altitude at - below which the vertical position of an aircraft is controlled by QNH

. Transition level : . lowest availble flight level (minimum vertical separation : 500 ft) / varies with QNH

. lowest usable flight level → setted 500 ft above transition level

. Transition Layer : airspace between TA - TL

. accelerated airflow = decrease static pressure = over - read altimeter

Temperature error

. affects pressure lapse rate : ① cold air = pressure decrease rapidly

② warm air = pressure decrease slowly

. from warm air to cold air ⇒ True altitude decrease

. from cold air to warm air ⇒ True altitude increase

. True altitude = actual altitude above mean sea level

. indicated altitude = barometric distance above mean sea level

. QNH = QFE + Elevation

Chapter 7

Humidity

- describe water vapor in the air
- latent heat: energy released - absorbed by a body during phase change ⟶ warm air hold more water vapor - latent heat

① Melting = from solid to liquid
- latent heat absorbed

② evaporation = from liquid to gas
- latent heat must be taken in from surrounding

③ Condensation = from gas to liquid
- latent heat released
- must be nucleus of matter

④ Freezing: from liquid to solid ice
- latent heat released
- needed freezing nucleus

⑤ sublimation = change directly from solid to gas = latent heat absorbed

⑥ deposition = change directly from gas to solid = latent heat released

- saturated air = no further evaporation can take place
- supercooled water droplets: water droplets exist in its liquid form below 0°C up to -50°C
  - exist where not enough freezing nuclei

① Absolute humidity = mass of water vapor per unit of volume
- g/m^3

② Specific humidity = $\frac{\text{mass of water vapor}}{\text{mass of air}}$ ⟨ g/kg ⟩
- increase with a decrease in atmospheric pressure

③ Relative humidity: how much water vapor is present ⟶ how much could be present if the air was saturated
- when temperature decrease ⟶ RH increase
- RH = 100 - [(temperature - dew point) × 5]
- RH = $\frac{\text{actual mixing ratio}}{\text{saturation mixing ratio}} \times 100$

- Dew point = temperature to which air must be cooled to be saturated
  - increase - decrease temp = no effect on dew point / dewpoint reached = effect
  - dry air = low dew point ⟶ must be cooled to saturate
  - humid air = high dew point / $T_d = T - (100 - RH)/5$
- cloud base = (Temp - dew point) × 400

- vapor pressure = pressure exerted by the water vapor molecules
  - water vapor molecules increase ⟶ vapor pressure increase
- saturation vapor pressure increase when temperature increase

Chapter 8

Stability

- adiabatic process = warming - cooling which no heat is transferred to or from the system
  - without external heat source - any transfer heat
- adiabatic process can be done by compression - expansion

① adiabatic cooling by expansion = parcel of air expand = volume increase ⟶ cooled internally
- parcel air rises ⟶ surrounding pressure decrease / RH increase

② adiabatic warming by compression = compressed = small volume ⟶ adiabatic warming (descending parcel)
- small volume = more interaction with each molecules / RH decrease

Dry adiabatic lapse rate
- unsaturated air - air less than 100% humidity
- 3°C/1000 ft - 1°C/100m
- Constant with altitude

Saturated adiabatic lapse Rate
- 100% humidity - SALR varies with temperature
- 1.8°C/1000 ft ⟶ 0.6°C/100m
- warmer saturated air ⟶ slower it cools = hold more moisture ⟶ more condensation = more latent heat released

- atmospheric stability = tendency of a parcel of air to rise - sink - remain level
  - depends rate of adiabatic → environmental lapse rate

Absolute stability
- tendency to return to its original position
- ELR < DALR - SALR ⟶ lower ELR = greater stability
- surface - low level cooling = ELR decrease = stable condition

weather =
① clouds = flat - layered clouds
② precipitation = fairly light intensity - persistent precipitation
- drizzle - fine rain - snow

③ visibility = poor visibility
④ turbulence = little - no turbulence

Absolute instability
- ELR > DALR / ELR > SALR
- creates up-draught ⟶ vertical cloud

weather =
① clouds = vertical extent
② precipitation = intense shower — large rain droplets
③ visibility = generally good - in shower of rain - hail will be very poor
④ Turbulence = strong vertical movement

Conditional instability
- the air is either stable - unstable (ELR between SALR - DALR)
- saturated air is unstable / dry air is stable

Neutral Stability
- ELR = DALR / ELR = SALR

weather = not defined

- at high level ⟶ very cold temperature = water vapor minimal = SALR is closer to DALR

Chapter 5

. Low pressure System (small diurnal variation in temperature)

.concentric isobares surrounding the centre ⟶ lowest pressure in the centre

.rising air ⟶ . high level it expands and cool = vertical cloud and precipitation

. clear the bottom of the atmosphere ⟶ good visibility

① deep depression ⟶ . greatest number of isobars (very low value at centre)

② shallow low ⟶ . few isobares (higher central value)

.stronger pressure gradient force ⟶ high wind speed

Formation ⟶ . differential heating = air rise

. upper atmosphere = divergence → at the surface pressure falls = convergence at surface

.at the surface = slowed by friction

. anti-clockwise flow (northern hemisphere) / clockwise around in the southern hemisphere

① Buys Ballot's law ⟶ with your back to the wind = low pressure at your left

Below 3000 ft ⟶ wind vector converges toward the centre low

① small heat lows : . develop during the day over land masses in summer

. warm air rise ⟶ convection / relatively strong — produce cloud

② large scale heat lows = . occur over the land masses North America - Asia in summer

. Global distribution of heat lows = . generated around equation region ⟶ strong thermal up currents

. migrates northwards — southward = between Tropic of cancer - tropic of capricorn

. influx at the surface toward equatorial lows ⟶ ITCZ

. large scale lows ⟶ . mid-latitude - polar front depressions

① Polar low = . short-lived atmospheric low pressure system (small scale)

. over the oceans ⟶ along main polar front both hemisphere = advected over relatively warm water

. tend to decay rapidly with landfall / last for anything 12-36 hours

. High pressure system (wider isobares)

. high surface pressure

. higher level = convergence ⟶ air is $\boxed{\text{subsiding}}$ ⟶ at surface = divergence

↓

.compressed air = temperature increase

. descending warm air ⟶ create inversion (temperature increase with altitude)

. poor visibility at lower levels / cloudless sky and light wind

. air near the surface = diverges — flows away from high-pressure ⟶ clockwise northern hemisphere / anti-clockwise southern hemisphere

① Warm Anticyclones : . occur at 30° N/S

. forming permanent sub-tropical highs = . 20°-40° N/S / subsidence of the hadley cell

. during summer = moving slightly north up / . during winter = moving slightly south up

. over atlantic ocean ⟶ Azores high — Bermuda high] ⟶ clear skies - light wind over land

Blocking anticyclone

. nearly stationary — moves slowly

. polar front depression moves from west to east ⟶ sub tropical high expand into high latitudes = deflect the depressions northward

. blocking anticyclone = . summer = sub-tropical high / winter = siberia cold anticyclone

Cold Anticyclones

. formed by large scale cooling of the air at the surface

. sinking air warms little ⟶ still remain cold = dry - sky clear (lack of precipitation)

. polar highs = . over large land masses

. siberia high / North america high

Cold temporary Anticyclones

. identified between polar front depression in the mid-latitudes

. pressure in the area between two large low pressure ⟶ higher

. produce weather to high-pressure

Col

- between two areas of high-pressure
- during summer = thunderstorm / during winter = fog

Chapter 9

Turbulence

① intensity = ① light = . slight - erratic changes in altitude ⟶ without changes in altitude - attitude

② moderate = . changes in altitude - attitude but aircraft remain positive / IAS may fluctuate slightly

③ severe = . large - abrupt changes in altitude - attitude ⟶ momentarily out of control

Mechanical - friction turbulence

- wind encounters obstructions ⟶ changes in direction
- occur at downwind of the obstruction
- more uneven (irregulate) = stronger turbulent layer

Thermal Turbulence

- air in vertical motion ⟶ changes in wind velocity
- rising air currents obstruct horizontal movement of air ⟶ turbulence at downwind
- most likely during = . warms days - clear sky / indicated by CB

Friction Layer

- layer air in which the surface influences the air flow
- The depth of friction layer depends ⟶ amount of thermal - mechanical turbulence
- hot days = higher friction layer

Mountain waves

- undulating waves ⟶ above - downwind of mountain / wind direction at lower side of rotors = opposite to prevailing wind
- extend 50 to 100 NM downwind - upwards to the Tropopause (up to FL 600)

requirements = ① wind speed must be at least = 15-20 kts (increase with height) ③ region of stability at mountain top ⟶ above - below unstable air

② wind direction = within 30° perpendicular to the mountain ⟶ no significant change with altitude

- rotor clouds just underneath the crest of mountains ⟶ strong waves downwind of the ridge
- cap clouds ⟶ winward side / flow off the top of the ridge ⟶ evaporating downward flowing leeward side

Defence = ① cross mountain range at 30°

② reduce speed = reduce risk of structural damage

Do not fly parallel and downwind / avoid rotor zone

Windshear

- variations in the wind vector - intensity - duration along flight path

① low altitude windshear = along : final app path - rwy - T/O and initial climb out

② vertical windshear = change of horizontal wind vector with height ⟶ kts / 100 ft

③ horizontal windshear = . change of the horizontal wind vector with horizontal distance
. kts / 1000 ft

updrafts - downdraft = changes vertical component of wind vector with horizontal distance

Cause of windshear = ① thunderstorm = severe windshear events ⟶ may strike from any side of a thunderstorm

② frontal passage = . marked temperature difference between two air masses = windshear

. warm front = windshear precedes the passage / cold front = occur behind the surface of the front

③ inversions = . at low level at night under high pressure system

. temp changes more than 10°C (between surface - 1000 ft)

Effects = ① increase tailwind = reduction of airspeed - lift decrease = sink below the correct glide slope . decreasing altitude during the app = stronger headwind component

② increase headwind = increase speed ⟶ increase lift ⟶ climbs above the correct glide

- downdrafts = vertical currents of air ⟶ changes in : airspeed - AOA (downdraft = aircraft sink - updraft = aircraft climb)

Microburst

① downburst = . strong downward moving air

. impact ground = forced outward = severe wind close to the ground

- formation = . dry air mixed with precipitation = water droplets to evaporate = decrease temp.

. cold air sink - plunges toward the ground

- go around - delay T/O - delay app

Turbulence Jet stream

- highest change of speed occurs = adjacent cold air ⟶ greatest CAT
- most severe = . strongest winds - curved jet stream - above and to the lee of very high mountains ranges

encounter = move to warmer side and descend

Chapter 10

. wind direction = . direction from which the wind blows

① aviation weather forecast = true north / weather reports = magnetic north

① veering = wind changes direction clockwise → convergence = wind backing

② backing = wind changes direction anti-clockwise → divergence = wind veering

. gust = mean wind speed during the past 10 minutes → maximum wind speed exceeds the mean speed by: ① 5 kts or more in local routine / 10 kts or more otherwise

. NH = ① wind from left = from high to low

② wind from right = from low to high

. pressure gradient force = . force acts from areas of high pressure → low pressure

. wind speed proportional to PGF

. coriolis force = . caused by the rotation of the Earth → $CF = 2 \Omega \rho V \sin\theta$

① Northern hemisphere = coriolis effect deflect to the right / Southern hemisphere = coriolis effect deflect to the left

. effect latitude = . increase latitude → increase coriolis force

. increase speed = increase coriolis force

. Geostrophic wind =

. only blows above the friction layer

. blow parallel to straight isobars

. PGF and CF act opposite from each other

. geostrophic wind speed increase as latitude decrease

. geostrophic force maximum at the poles

. Gradient wind =

. above friction layer

. blows along curved isobars

. 3 forces = PGF - CF - centrifugal force

① gradient wind around depression = . centrifugal force opposes PGF → reduce wind speed

. gradient wind speed < geostrophic wind speed

② gradient wind around anti-cyclone = . centrifugal force acts in the same direction PGF = wind speed increase

. CF increase → gradient wind > geostrophic wind

. Surface wind:

. below friction layer

. surface wind speed increase as latitude decrease

. surface friction reduces the wind speed → Coriolis force decrease

. wind blows across the isobars toward low-pressure

. below the friction layer = ① convergence low pressure — divergence high pressure

① from surface to friction layer = . wind veers and speed increase

② descend into friction layer = . wind back and speed decrease

. over the land → wind speed decrease (friction force) / deviates considerably from geostrophic wind → NH = wind back 30° and reduced 50% — SH = veers 30° and reduced 50%

. over the sea = small friction = small reduction speed / small deviation → NH = wind back 10° / SH = veer 10° → speed reduce 70%

. Diurnal variation =

. during the day = low-level wind mix with higher wind level → surface wind higher → veers during day

. during the night = no mixing effect → surface wind relatively slow → backs during night

Sea breezes (only during the day)

. heat the land = warm air = rise up → low pressure over the land

. cooler air from sea to land

. lead vertical cloud formations → develop thunderstorm

Land breezes (only during night)

. air over the land → cooler and denser = sink / air travel over the sea = warms

. air from land

Anabatic winds

. flow up sloping terrain

. on the slopes → warms = flows up the sides

. in the middle valley => cooler — sink

. rising air condenses to form cumuliform clouds

katabatic wind (during night)

. flown down sloping terrain

. cold air sinking toward the valley → temp falling below dew point = valley fog

① Mistral → . relatively cold wind → extend up to tropopause

. driven by high-pressure over NW Europe

. comes from two different directions = NW - NE

① North-east = . fed by low-pressure in Genoa

. colder - stronger

② north-west = cloudless skies — clearing

② Bora => . cold - strong — NE wind

. high-pressure over the land → low pressure over adriatic sea = run down throught the valley

Foehn wind

- warm - dry wind ⟶ blow on the leeward
- cloud - rain on the upwind / warm - dry - clear skies downwind

Chapter 11

upper wind

- much faster = reduction air density / different temp of air

① Thermal wind

- cold air masses = pressure decrease rapidly = low-pressure above cold air
- warm air masses = pressure decrease slowly = relatively high-pressure above warm air

⟶ flow from warm air to cold air (affected by Coriolis effect)

- Global upper wind pattern: ① westerly flows = • air is colder at the poles than equator
  - ② easterly flows = • during summer ⟶ heat equator at latitude 23.5°N = temperature difference = upper easterly wind
    - • upper easterlies are not as strong

① Hadley cell = between Equator - subtropics
② Ferrel cell = between subtropics - temperate latitude
③ Polar cell = between temperate latitudes - poles

Jest stream

- formed by boundaries between warm — cold air = large temperature difference
- velocity greater than 60 kts
- 2000 NM long — 200 NM wide - 2 NM deep

mid - latitude = length 1500 NM - width 200 NM - depth 12 - 18 000 ft

① Sub - Tropical Jet stream =
- permanent and occur in both hemisphere / westerly Jet stream
- located in warm air
- temperature difference between Hadley - Ferrel cells
- move with heat equator ⟶ • December = 25° to 40° / • June = 40° to 45°
- Jet core at 40 000 ft (200 hpa) ⟶ varies with season : in winter = lower altitude

② Polar front Jet stream =
- permanent — both hemispheres ⟶ presence of streaky clouds
- located in cold air
- temperature difference between Ferrel - polar cell
- significant change in direction
- frequently start and stop over land
- 50 to 200 NM behind cold front - 300 to 500 ahead warm front
- occur between 40 - 65°N / 50°S ⟶ moves northward in summer - moves southward in winter
- associated by polar front depressions
- Jet core = at 30 000 ft but varies with seasonal ⟶ core is located on warm air

③ arctic front Jet stream =
- seasonal Jet stream — northern hemisphere ⟶ only winter
- between polar maritime air — arctic air ⟶ over North Atlantic ocean
- Jet core = 20 000 - 30 000 ft

④ Tropical easterly Jet stream:
- only northern hemisphere — during summer (10° - 20°N)
- temperature difference between: hot west African continent - hot Indian sub-continent
- runs from south China Sea westward across southern india
- Jet core = 45000 ft

Clear air turbulence

- rapid change of wind speed — wind direction
- most pronounced = cold air ⟶ greatest windshear

CHAPTER 12

- cloud are classified =
  - height of the cloud base ⟶ Troposphere is divided into three levels = low · medium · high
  - shape of cloud ⟶
    - ① stratiform cloud = flat · stratified with large horizontal extent (little vertical extent)
    - ② cumuliform cloud = vertically extent · heaped appearance
    - ③ cirriform clouds = only at higher level ⟶ fibrous · wispy
    - ④ Nimbus = rain · producing type of cloud

① High · level clouds =
- Cirrus ⟶ · white filaments · white patches ⟶ fibrous · silky sheen
  - formed by ice crystals ⟶ no precipitation
- cirrostratus =
  - transparent · whitish cloud ⟶ veil · like ⟶ smooth appearance
  - halo phenomena
  - formed ice crystals ⟶ little vertical depth (no precipitation)
- cirrocumulus =
  - thin · white patchy
  - formed ice crystal · little vertical depth ⟶ no precipitation

② medium level clouds =
- altostratus =
  - greyish · bluish cloud sheet ⟶ cloud layer of striated fibrous
  - produce light continuous precipitation ⟶ may not reach the ground
- altocumulus =
  - white or grey ⟶ sheets · layers · patches of cloud
  - light showery precipitation (may not reach the ground)
- nimbostratus =
  - grey cloud layer
  - continuous rain or snow (moderate to heavy continuous precipitation)
  - can extend into low · high altitude

③ low clouds =
- stratus = · grey · layered cloud with a uniform base (ragged patches)
- stratocumulus =
  - whitish sheets, patch type
  - produce no precipitation
  - associated with virga

low · vertically developed clouds ⟶ · warmer air at the surface = higher cloud base
- cumulus = · develop vertically
- cumulonimbus =
  - heavy and dense cloud (extend vertically)
  - spread at the tropopause to form an anvil shape
  - heavy showers of rain · hail
  - can be embedded
- Towering cumulus = · vertical growth ⟶ bulging upper a cauliflower

- lenticularis = · sharply defined lens shape
  - indicate mountain wave activity
- castellanus = · middle level atmospheric instability ⟶ possibility thunderstorm
- fractus =
  - ragged appearance
  - beneath a storm in the turbulent mixing air

LOW LEVEL CLOUDS	BASES 0 ft – 6 500 ft WATER DROPLETS	STRATUS ST STRATOCUMULUS SC CUMULUS CU CUMULONIMBOS CB NIMBOSTRATUS NS Cumulus and cumulonimbus will, however, have significant vertical development and will extend from LOW to HIGH levels. CB could extend into lower stratosphere.
MEDIUM LEVEL CLOUDS	BASES 6 500 ft – 23 000 ft	ALTOSTRATUS AS ALTOCUMULUS AC NIMBOSTRATUS NS – may also be classified as medium level. Characterised by prefix "Alto"
HIGH CLOUDS	BASES 16 500 ft – 45 000 ft ICE CRYSTALS	CIRROSTRATUS CS CIRROCUMULOS CC CIRRUS CI Characterised by prefix "Cirro".

- Virga = · precipitation falling that don't reach the earth's surface
  - evaporates in warmer / drier conditions at lower level

Chapter 13

- lower dew point (relative temp of the air parcel) ⟶ higher cloud base
- cloud dissipation = · increased warming in stable conditions
  - general changes in characteristics of air mass

Precipitation

① process ⇒ · Bergeron · Findeisen: · process of droplets comes in contact with freezing nuclei = ice crystal and supercooled water droplets
- low vapour pressure around ice nuclei ⟶ high vapour pressure around water
- involves supercooled water droplets ⟶ ice crystal grow at the expense

· coalescence theory = · formation of precipitation in clouds warmer than 0°c
- warm cloud with tops warmer than −15°c

· Freezing rain = · falls through warmer air before reaching ground

① Drizzle = · diameter = less than 0.5 mm / visibility = 500 to 3000 m
- no perceptible splash on impact
- stratiform only

② Rain = · diameter = 0.5 mm to 5.5 mm (average 2 mm)
- Rain bearing cloud = Nimbo · nimbus
- average size of drops increase with intensity of upward motion (cumuliform)

③ Snow = · ice crystal branched
- The colder it is = smaller snowflake
- large snowflakes = higher moisture (worse visibility)

④ Snow grains = · diameter = less than 1 mm (white · opaque grains of ice)
- Temperature between 0°c — −10°c
- from stratus · fog

Snow pellets = · conical with a diameter (2·5)
- bounce and break on contact

· Ice pellets ⇒ · larger than snow pellets ⟶ transparent and spherical · irregular
- diameter less than 5 mm / from layered cloud / bounce when hit hard ground
- when reached the ground = at higher altitude these ice pellets were not solid (warm front)
- freezing at higher altitude

Precipitation Type	Cloud Type	Precipitation Properties
Drizzle Freezing Drizzle Snow Grains	ST, SC or NS	Diameter less than 0.5 mm. Visibility: 500 to 3000 m. Imperceptible impact. Drizzle does not make a splash on the ground.
Rain (continuous)	Thick AS and NS	Diameter from 0.5 mm to 5.5 mm. Visibility: 3000 m to 10 km. 1000 m in heavy rain. Drops have to be large to overcome the up- currents in the cloud to fall. Larger drops break up into smaller drops as the rain falls.
Snow (continuous)	Thick AS and NS	The lower the temperature the smaller the flake size. Surface temperature must be < 4°C for snow to reach the ground before melting.
Hail	CB	Diameter: 5 to 50 mm. Weight: up to 1 kg.
Rain (intermittent) Snow (intermittent)	Thick AS and SC	
Rain Snow Showers	Heavy CU CB	
Sleet		A mixture of rain and snow or snow, which has partially melted in the descent.

- Continuous: No breaks in the precipitation for more than 60 minutes. This type of precipitation only falls from stratiform type clouds.
- Intermittent: If precipitation falls from time to time from extensive clouds with no marked clearances less than 60 minutes. This type of precipitation only falls from stratiform type clouds.
- Showers: Showers of rain, snow, sleet or hail, are always associated with cumuliform clouds.

Chapter 14

① Requirements = .unstable air .trigger to initiate uplift

.adequate supply of moisture

② stages = .building stage = .contain only updrafts .between 15-20 minutes

.fed with moist air from the base - the side

.mature stage = .updrafts - downdrafts / between 15-30 minutes

.water droplets start to fall ⟶ .partly evaporates = latent heat absorbed = fall temperature ⟶ cooler air descends

.downdraft spread outward = gust front or leading edge of cold air

.cold air from downdrafts sink under warmer air ⟶ lifting warm air = form cloud

.precipitations create static electricity

.dissipating stage = .only downdrafts

.due to = .no more moist air left .downdrafts overcome updrafts

.no initial trigger

.precipitation stops / cloud base arise

③ anvil formation = .updraft during mature stage ⇒ reaches tropopause ⇒ inversion above tropopause

.inversion over the tropopause ⇒ prevent further vertical development ⇒ anvil shape

.light wind ⟶ anvil spreads out ⟶ indicates direction of the upper wind

.Multi-cell and super cell thunderstorm = .persistently rotating updraft
(4hr or more)

.feed itself with moist air

.upper wind vary with height ⟶ storm leans to one side

.precipitation doesn't fall into rising air ⇒ no reduction in the strength of updrafts

.move over long distance = heavy rain-hail

.Heat thunderstorm = .Trigger is thermal uplift — convection

.lapse rate steepens as the surface temp rises ⇒ greater instability

.moist air lifted up

.air mass thunderstorm = .cool air mass moves over a warm surface

.altocumulus castellanus = middle level instability

.frontal depression = .cold air mass undercuts a warm air

.ahead cold front ⟶ puts warm air under cold air = instability

.Towering cumulus ⟶ embedded thunderstorm

.Squall line ⇒ .line of thunderstorm ⟶ just ahead cold front

.Tornado ⇒ .funnel cloud with touches the surface ⟶ diameter 100-300 m

.moves across the surface at 20-40 KT / rotation speed exceed 200KT

.occur in isolated - squall line

.extending downward from the base of thunderstorm

.caused = .vertical wind shear with moist air - dry air comes from different direction

.very small extremely low pressure zone = circulating at higher speed

.in USA occur = spring - early summer

. Dust devil = .upward motion of air from the ground

.small scale ⟶ small diameter

- lightning => • large electrical charge separation
  - • heats the air around it ⟶ cause air to expand = cause pressure wave => Thunder
  - ① Intra-cloud = inside the cloud ⟶ between different charge regions in the cloud
  - ② cloud to air = discharge jumping from a cloud into clear air
  - ③ cloud to cloud = negative charged finds positively (from cloud to cloud)
  - ④ cloud to ground = between cloud - ground
- St. Elmo's fire => • as the static electricity increase ⟶ electrical potential strong
  - • discharge between object - air
- Thunderstorm avoidance => • above 20 000ft => 20 NM / below = 10 NM
  - • vertical separation = 5000 ft
- minimum distance to avoid = 20 NM

Chapter 15

① supercooled water droplets => • liquid droplets below 0°C (0° to -40°C)
- • remain liquid due to lack freezing nuclei
- • freeze instantly into contact with a solid surface

• 0° to -20°C = large - small supercooled water droplets	• greater vertical force = larger size
• -20°C to -40°C = small supercooled water droplets	• large SCWD freeze slowly ⟶ flows back across the aircraft's surface = freezing = release latent heat
• below -40°C = frozen	

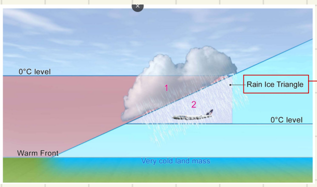
② Hoar frost => • over cold surface ⟶ moisture is present
- • cools overnight => water vapour desublimates direct to ice
- • occur when descends through warm air ⟶ after cold soaking

③ Rime ice => • $\boxed{\text{small SCWD}}$ come into contact => airframe colder than 0°c
- • look opaque — white / builds forward part of the wing
- • encountered colder — higher levels of cloud (strati clouds)
- • easy to remove
- • difficult to see through

④ Clear ice => • leading edges come into contact with large SCWD => spread out
- • smooth surface ⟶ builds up slowly
- • greater risk => lower - medium level of cumuliform / nimbostratus
- • created by cold rain

Freezing rain / drizzle = • supercooled at temperature close to 0°c
- • drop form in relatively warm cloud ⟶ falling through a very cold layer
- • happens nimbostratus

⑤ mixed ice => • combination of clear ice - Rime ice
- • some flow-back and some forward build up



- • occur ahead of warm front / cold land mass
- • escape climbing

- Cumulus cloud => • risk of airframe icing => 0° to -20°c (moderate to severe icing)
- Stratiform cloud => • comprised water down to temperature of -15°c ⟶ severity icing = 0° to -10°c
  - • light to moderate icing
- altostratus - altocumulus => • produce large SCWD / orographic uplift increase severity of icing
  - • between 0° to -15°c => moderate - severe icing
- nimbostratus => • increase water droplet concentration = moderate icing

- ice crystal icing => • occur in convective weather
  - • lift significant moisture => freeze small ice crystal
  - • high IWC = high ice crystal ⟶ found in the upper level
  - • undetected by weather radar
  - • To avoid it => fly upwind

- icing into carburettor => • OAT is between -7°c and 21°c = relative humidity above 80%

Inversions

- Temperature inversions => • light wind below the inversion layer / strong wind just above ⟶ creates wind shear
  - Through inversion => reduced aircraft performance => reduced thrust - lift
- descending through inversion => performance increase and visibility decrease
- climbing through inversion => performance decrease and visibility increase

② valley inversion => • cooling of ground (long-wave radiation) + nocturnal down-slope wind
- Temperature of upper parts => becomes low ⟶ heavier and cold : descend along mountain slope ⟶ push upward warm air
- above inversion => windshear

Chapter 16

- fog => suspension of small water - ice crystals reducing visibility to less than 1000 m (FG)
- mist => • reducing visibility between 1000 m - 5000 m (BR)
- Haze => • small dry particles => invisible to the naked eye / reduction visibility 5000 m or less

- Smoke => small particle produced by combustion / 5000 m or less
- dust => • visibility reduced to 5000 m or less
- Sand => reduction in visibility to 5000 m or less

① Fog => • cloud on the surface ⟶ air becomes saturated / can start to form less than 2°C diff. between dew point - temperature
- sufficient cooling — ample quantity of condensation nuclei

① Radiation fog (shallow fog) => • forms overnight over the land when the ground loses heat by radiation / prevail temperate regions (high-pressure system — calm over land)
- ground cools the nearby air ⟶ patchy fog / extend up to few hundred feet
- conditions = • high relative humidity • clear skies — long nights • light wind (2-8 kt)
- dispersal => • warmth of the sun ⟶ air above the dew point • wind speed increase

② advection fog => • warm and moist stable air moves over a cool surface => cools the air at dew point
- up to 15 kts wind speed

③ steam fog => • very cold, stable, dry light wind flow over a warm open body of water
- cold dry air cools evaporating warm, moist air above the water ⟶ condense
- dissipate = strong wind / temperature warms up

④ Frontal fog => • rain falling from warm air ⟶ saturates the cooler air close to Earth's surface
- hundreds of mile long
- Stays with the front / disappear when the front passes

⑤ Up-slope fog => • air is forced up ⟶ cools adiabatically : dew point reached
- forms on the upslopes ⟶ evaporates as the air descends

- Volcanic ash => • extreme reduction visibility ⟶ extend many hundred

① drifting snow = • raised from ground by the wind ⟶ less than 2 m (6ft)

② blowing snow = • snow lifted from the ground ⟶ suspended by strong wind
- height 2m (6 ft) or more / reduce the visibility

③ dust and Sand => • wind exceeds 15-20 kt ⟶ picked up and carried upward by turbulence
- significant reduced visibility | heavy => • below 200 m sky obscured / moderate = • below 200 m sky not obscured • 200 - 600 m

Visibility in precipitation will be highly dependant on the type of precipitation and on its intensity:
- Drizzle: **500 to 3000 m**
- Rain:

- **3000 to 5.5 km**
- 1000 m in heavy rain
- As low as 10 m in the tropics

- Snow:

- Moderate: 1000 m
- Heavy: 50 to 200m
- Drifting: <2 m above the surface, will reduce the above
- Blowing: >2 m above the surface, will GREATLY reduce the above.

Chapter 17

. air masses => .large body has uniform temperature - moisture - pressure horizontally

.obtain initial properties from surface over lie

① classification = _first letter => .humidity characteristics (maritime - continental)

_second letter => .source region thermal (Equatorial - tropical - polar)

_third letter => .air mass temperature (warm - cold)

.air mass moving to warmer location => increase ELR = unstable (warms below)

.air mass moving to colder location => decrease ELR = stable (cooled below)

① Tropical maritime => .source => sub-tropical high-pressure belt over oceans (Azore high)

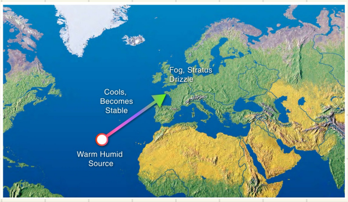
.warm - moist air => high humidity levels

.moves north-east toward Europe => .during winter => .fog - low cloud with drizzle - poor visibility

.during summer => surface heating => disperses any cloud

.moving west toward USA => .Atlantic subtropical high (Bermuda high)

.across warmer sea => instability => cloud thunderstorm



② Tropical continental => .source => northern Africa — southern Europe

.characteristic => warm - low humidity ⟶ high temperature - cloudless skies

.moving northward => cooled below => very low dew point (humidity increase = moves over the water)

③ Polar maritime => .source => polar region (Northwest area of North atlantic)

.characteristic => very cold - dry

.moves southward => over relatively warmer Atlantic ocean => warm and increase humidity => unstable

.during summer => more vigorous uplift - thunderstorm

④ Artic maritime= .winter air mass (much colder - less moisture)

.moves southward => slight warming => Unstable => snow shower

⑤ Returning polar maritime => .extended route across a long sea track

.moving south => become unstable / .moves north => become stable

. altocumulus castellanus

⑥ Polar Continental => .summer => .warm dry air in central Europe - Russia (warm up significantly)

.produces => warm dry - hazy conditions

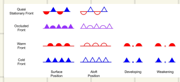
.reaches UK => long track over North sea ⟶ instability as passes it warm land

.winter => .source => cold dry air in Russia

.produce very cold - clear conditions in Europe mainland => stable

.in the UK => picks up moisture from warmer sea => instability

Chapter 18



. fronts => conjunction between two different air masses

① Polar front => .boundary => between polar maritime - tropical maritime air (Polar cell - Ferrel cell)

.most pronounced over the oceans

.average position: about 50° N/S (.more stable at south hemisphere / variable at NH)

① winter => extend from Florida to south-west of UK

② summer => extend from Labrador to Northern Scotland

② Artic - Antarctic fronts => .boundary => between cold air of poles - warm polar air

.in winter => move into lower latitudes

③ Mediterranean front => .boundary => between polar continental air (Europe) — warmer tropical continental air (North africa)

.only in winter ⟶ sea warmer than land = warm air rise = creates low-pressure zone

.produce very active weather ⟶ large convective storms and wind

④ ITCZ => .global zone of convergence => Trade winds (drawn surface air in)

.intense surface heating => intense thunderstorms

.position varies with season => depend on latitude of heat equator — differential heating of land - sea

Polar front depression => . six stage of development => . cyclogenesis => . formation depression – anticyclones along polar front

. driven by flow dynamic of polar front jet — air masses movement

. sinous boundary zone ⟶ two different air masses = . warm mass to the south

. cold mass to the north

. moves SW to NE ⟶ move in the direction of isobars in warm sector

. upper winds blow parallel to polar front (from west to east)

. surface wind => blow across the isobar toward the low

① **WARM front :** . Tropical maritime air being forced toward polar maritime => slide up

. slope = 1:150

. shallow frontal slope => produce stratiform cloud

① cloud - precipitation - visibility => . arrival high cirrus

. get closer = cloud base slowly into altostratus => rain bearing 200 NM from front

. closer to front => nimbostratus ⟶ rain falling evaporates => saturate the air just ahead of the front

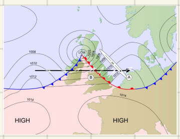
. in winter => freezing rain / drizzle / . in summer = extensive period of rain

. visibility steadily worsens / all warm front weather => at and ahead of surface position (extend 400 - 500 NM)

Flying towards the west, the pilot will observe the following sequence of clouds:
Cirrus CI: at FL250-350 as far as 600 NM (1100 km) ahead of the front.
Cirrostratus CS: at FL200-250 gradually replace the CI (about 800 km from the surface front)
Altostratus AS: at FL150-200 as the front gets closer.
Nimbostratus NS: between 6000 - 8000 ft, approx. 150-200 NM (270- 370 km)away (in some cases up to 300 NM) until the front.
Stratus ST or Stratocumulus SC: can be encountered below the NS
Frontal FOG can sometimes be encountered 20-50 NM ahead of the frontal ground surface.

② wind =>

. Jet stream => . found beneath the polar air tropopause (300 - 400 NM ahead of warm front)



. geostrophic wind => . blow parallel to isobar with low on the left

. surface wind => . blow across the isobar toward the low

. ahead of warm front => . wind is approximately westerly => wind is light

. front approaches => . wind slowly back to south - south westerly => wind speed increase

. at warm front => . sharply veer and decrease slightly wind speed

③ pressure => . as the front approaches => pressure falls

. behind warm front => decrease slightly

. at warm front => stop falling (lowest value)

④ movement => . moves parallel to the isobar behind front (about 2/3 geostrophic wind)

. move at a speed 10-15 kts

	Ahead of a warm front *(marked as "1" in the attached figures)*	At the warm front *(marked as "2" in the attached figures)*	In the warm sector *(marked as "3" in the attached figures)*	At the cold front *(marked as "4" in the attached figures)*	Behind the cold front *(marked as "5" in the attached figures)*
SURFACE W/V	Speed increasing, slight backing, usually southerly.	veers sharply, windspeed decreases slightly.	Steady, usually from the SW.	veers sharply (strong gusts and squalls likely)	Steady or slight veer to NW, speeds decrease.
TEMPERATURE	steady low.	Sudden rise.	Steady.	Sudden decrease	remains steady (cold)
PRESSURE	Steady decrease.	Stops falling (lowest value)	decreases slightly	Starts to rise (lowest value)	increases slowly
CLOUD	Increasing to overcast, base lowering, Ci, Cs, As, Ns.	overcast layer of NS and ST, base very low	BKN to OVC, some large breaks may occur, base low of St, Sc.	BKN to OVC with CU and CB, base low but rising, possible Ns.	BKN to OVC, base lifting, occasional Cu, Cb.
PRECIPITATION	continuous light rain from AS and then moderate to heavy continuous from NS.	Moderate or heavy continuous rain/snow from NS	Light rain, drizzle	Heavy rain or snow showers, thunderstorms and hail possible.	same as at the cold front, then no precipitation, later occasional showers from CU and CB.
VISIBILITY	gradually reducing to poor as front approaches.	Very poor, fog can occur.	Poor	Good, except in precipitation.	Very good, except in showers.

② **Warm sector** => . air within sector => tropical maritime – tropical continental

. over atlantic - NW Europe => . tropical maritime => . in winter => widespread low stratus - stratocumulus

. in summer => fair weather with cumulus over land

. Tropical continental => . clear sky

. pressure falls slightly / wind = remains constant from west - south - west

④ **Cold front** => . cold air underneath warm air => lifting warm air => increase ELR = instability

. steeper slope / weather band 50 - 100 NM

. produce thunderstorm => intense line of cumulonimbus (can be embedded with NS - AS)

. moves parallel to the isobars of warm sector

. faster than warm front

. slope 1:50 - 1:80

① approaching cold front => line of CB with shower - gust

2 at front => polar maritime air warmed below => unstable

3 after the front => . cloud base rises / precipitation reduces / pressure rise ⟶ wind speed decrease

. approaching the front => wind veers sharply from westerly to North - westerly

. Jet stream => . beneath polar air about 50 - 200 NM behind the surface of the cold front

⑤ **quasi - stationary front** => . moving < 5kts

. above friction layer ⟶ wind blows along the front

. in friction layer => slight inflow air => some uplift

. Stable stationary front => . stratiform clouds form => drizzle - light rain / snow - light sleet

. unstable stationary front => . cumulus will form => embedded within stratiform cloud => wide area of shower - frontal fog

– ana front => . rise more air => due to rapidly moving cold air behind the front => lifting warm air

. more active => heavy precipitation - deep layer of cloud / slow - moving cold front

– kata front => . warm air moving down the frontal surface => stable condition

. main zone of cloud - precipitation developing ahead of the surface frontal

. light precipitation

. fast - moving front

. **Blocking Anticyclones** = . areas of high pressure almost stationary (40° - 70° N) => sub - tropical Azore high - siberian - greenland low

. start from a ridge of high - pressure => breaks off and establish itself => separate anticyclone

. persist for several days => warm - dry in summer / stable - cold in winter = potential mist and drizzle

. maintain higher pressure up to tropopause

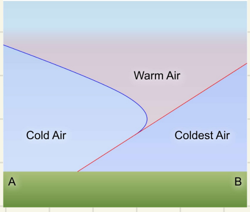
.occluded front

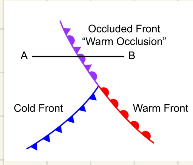
.warm occlusion => .cold front rides up and over warm front

.warm front remain at surface

.air ahead warm front => colder than air behind the front

less cold air rides over the leading colder air (cold air aloft)





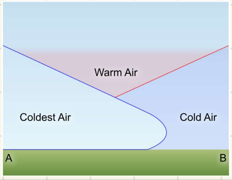
.embedded CB => warm-moist and unstable air / precipitation ahead of surface position

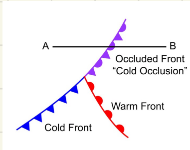
.cold occlusion => .cold front underneath the warm front

.cold polar maritime air ahead front = warmer than polar air behind front

.common in summer => .air ahead has been warmed by land => cumulonimbus

.warm moist and stable





Chapter 19 (non-frontal thermal depression)

① equatorial low-pressure belt => .rising air at the heat equator => diverges at tropopause to form a wide low pressure

.belt of thunderstorm

② Thermal depressions => .air warmed by the surface => diverges at higher levels = low pressure at surface

.widespread thunderstorm

.Asian low => .intense surface heating in summer => low pressure belt

.draw warm-moist air from Indian ocean into land mass => enormous band of rainfall => southerly monsoon

.Tropical Revolving Storm

.produce extreme wind speed - torrential rainfall - TS and tornadoes

.average diameter 500km/300NM / Thermal depression: exceed 33kts - tropical cyclones = exceed 63 kts

.in the eye => area of relative calm - clear skies

.originate within 5° to 15° of equator

moving westward away from equator => turning east after crossing the tropics

.in southern hemisphere => .start westward / south-westward ⟶ turn gradually more to the south

① conditions => .large body of warm ocean water (at least 26°C)

.unstable atmosphere ⟶ relative moisture

.minimum distance from equator (latitude 5° - 25°) away coriolis force

.pre-existing near surface / low magnitude windshear

.storm's energy => . massive amount of latent heat during condensation over warm ocean

② stages => ①.Thunderstorm over tropics moving westward by easterly trade wind

.lasting for more than 24 hr

②. lowering pressure - organised circulation in the centre of TS

. wind exceed 33 kts (Tropical storm)

3-4 .more organised => circular rotating

.surface pressure continues to drop / wind speed exceeds 63 kts

.highest wind => .fastest winds => .NH => right of the track

.SH => left of the track

.Eye => .diameter = 20-50 km (10-20 NM) / can be observed by satellites

.within the eye => lowest pressure and calmest conditions

.air in the eye is warmer than air in the eye wall

.descending air => dry and warm at the DALR

.strong updraft - downdraft

.Eye wall => .most active CB - strongest wind - severe turbulence

.enclosing eye

.Seasonality — frequency => ①Hurricanes => .Northern hemisphere — Atlantic and Eastern Pacific

.average TRS 17/18 ⟶ about 6 becoming hurricanes

.mainly from July to November (Summer — Autumn)

② Cyclones => .southern hemisphere - western pacific (Australia) — East coast of Africa

.9 per year

.mainly from December to April

.cyclones => .indian ocean (occasionally)

.12 times per year ⟶ March - december

.Typhoon => . NH (western Pacific) — south Chinese sea

.20 times per year ⟶ June to November

highest frequency TRS

.East of darwin => average 9 tropical cyclone x cyclone season

.west of darwin => average 5 tropical cyclone x cyclone season

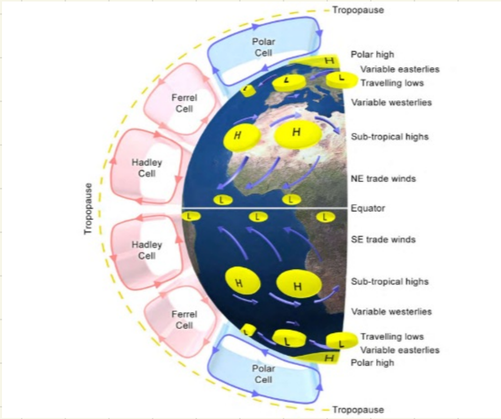
- **Orographic depressions :** • low-pressure area ⟶ form to the lee of range of mountains
  - • air flows down the lee side ⟶ warming – compressing => convergence at the surface
  - • a cold front approach mountain range => unstable air lifting => heavy banks of Cb – line squalls – heavy shower – thunderstorm

- **Polar low =>** • small scale ⟶ short-lived low pressure
  - • found over ocean areas
  - • produce severe weather – heavy precipitation

- **Secondary depression =>** • small depression within the circulation of main depression
  - • embedde with primary

Chapter 20

① Global circulation : ① **Hadley cell :** • hot air generated at heat equator => rising => equatorial low-pressure belt
- • at higher latitudes => cool air starts to sink => dry – cloudless skies => sub-tropical high-pressure belt
- • some diverging air at sub-tropical high-pressure => flowing in to ITCZ => north-east – south-east trade winds
- • NE trades winds => between 10°N – 20°N in NH / • SE trade wind => between 10°S – 20°S in SH



② **Ferrel cell :** • diverging air at higher latitudes => converges toward the Equator from pole => polar front depression
- • affect mid-latitudes regions

③ **Polar cell :** • rising polar air => diverges at tropopause => toward poles => cool and sink on polar region

② Seasonal movement = • cells and their associated high-lows => move with heat equator
- • from March to late July => heat moving northward (23.5°N maximum)
- • from August to late december => heat equator moves toward south

③ Global wind patterns =

① **Westerlies of temperate latitudes :** • between subtropical high – polar front (40° to 60°)
- • caused by => turning effect of Coriolis => poleward outflow from subtropical high
- • mainly over the ocean / much stronger in SH => no land masses to disrupt (Roaring Forties)

② **Doldrums** => • extensive area of calm ⟶ nil wind conditions
- • at the surface in the ITCZ => converging wind cancel each other

③ **Horse latitudes** => • light – variable wind conditions => in sub-tropical high-pressure belt
- • between 30°N – 35°N ⟶ widely spaced isobars

④ **Trade wind** => • permanent wind => in the equatorial region (10°N – 10°S)
- • from sub-tropical high toward the ITCZ => prevalent over oceans
- • NH = NE trade wind / SH = SE trade ⟶ crossing equator = NE trade wind back / SE trade wind veer
- • Travelle over warm surface => moist

⑤ **Monsoon** =>

① NE Monsoon => • from siberian high => cool and dry => clear weather
- • affect => Bangladesh – Burma – Thailand – SE india – Sri Lanka
- • over the sea => pick up moisture = TS – heavy precipitation
- • occuring during winter

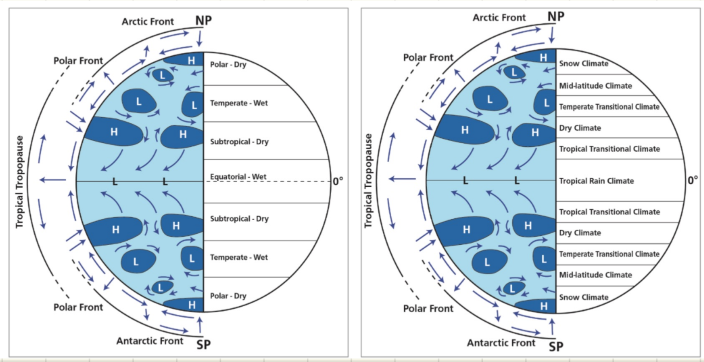
② SW Monsoon = • produced by SE trade wind
- • from sea => high moist = heavy Cu-Cb with large scale TS
- • affects => • all of india – Sri Lanka – Burma – West of malaysia
  - • West african coast – Guinea – Ghana and North Nigeria

• NW Monsoon => • extension of NE monsoon => back on crossing the Equator southbound
- • bring Cu – Cb – TS ⟶ North Australia – New guinea

⑥ waves =>

① **Easterly wave** => • trough of low pressure => over west africa (5° – 20°N)
- • moving toward Caribbean
- • occur during summer – autumn => associated TRS

② westerly wave => • associated with polar front depression
- • moves from west to east
- • originate over ocean



.climate classification

① Tropical rain climate => .from equator to 20° .high humidity - convective weather .mean temp = 28°C / coldest month > 18°C / RH = 80%

.highest annual rainfall (no dry season) .under influence of the ITCZ .freezing level = FL 150

.high temperature = little variation .Trade wind zone

② Transitional zone (Tropical savannah zone) = .limits of the ITCZ

.Two distinct season = dry season (winter) - wet season (summer)

③ Arid zone (dry climate): .between 20° to 40° .hot summer => large daily - seasonal variation in temp.

.divide into = .desert region = less precipitation .Trade wind

.steppe regions = higher amount of rainfall .precipitation => in summer on equatorial side / winter on polar side

④ mid latitude climate => .between 40° to 70°

1 cool temperate zone => .at higher end of the latitude band

.wester wind with the frequent passage of frontal depression

.no dry season - seasonal variations

② warm temperate zone (Mediterranean climate) = .significant seasonal variation (transitional climate) .Frontal - thermal depression

.winter = cool - wet / summer = .sub-tropical high-pressure with arid zone => hot dry

.NW europe => Azores high predominates

⑤ sub-arctic climate => .dominated by tundra - permafrost (Northern EUROASIA - CANADA)

.long - cold - dry weather / hot summer

.average temperature = below 0° for long periods

⑥ Polar zone => .extreme seasonal variations .constant darkness - constant daylight .warmest month < 10°C

.extreme cold .little - no precipitation

.persist polar high-pressure / cold - persistent easterlies

.ITCZ => .Trade wind zone => flowing toward the Equator => more humid - warmer = unstable

.extensive Cu - Cb - thunderstorm

.over the lands => ITCZ farther from equator => warms much more / cold water prevents the ITCZ from moving south

.Tropical squall lines => .line of thunderstorms => much longer (600 km long)

.violent gust line - intense downdrafts - extremely heavy precipitation

Regional weather characteristics

① indian subcontinent => .during summer = .land warms up = large scale heat low = draw moist air from sea

.heavy TS (SW monsoon)

.during winter => .land cools down => dry with little weather

.Siberian high develop wind => NE monsoon

2 West africa => .in August => .ITCZ runs through middle of west african .in January => .ITCZ moves southern

.warm - moist air from atlantic => thermal - convergent uplift => unstable .Harmattan => .dry - dust north - east winds from Sahara

.SW monsoon .reductions in visibility

.easterly wave

③ North East ASIA => .in winter => .cold - dry (driven by Siberian high) .in summer => .Asian low => driven warm - moist - unstable SW wind

.fog - low stratus can form along eastern coastline .rise ITCZ to 40° N

.large - frequent typhoons

④ Australia => .Northern Australia => .during december - January => . NW monsoon → until April | .rest of Australia = .influence under sub-tropical high = warm - dry air

.strong heat lows .in June - July => .polar front moves into the bottom => frontal depression with warm temporary

.Polar air outbreaks (abnormal winter occurrences)

- polar vortex => large anti-clockwise of cold air
- during winter => .cold polar air outbreak extending into the lower latitudes = unseasonably heavy snowfall - cold air - frigid temp

.Cold air drops => .cold air located above warm areas in the upper troposphere

cold air aloft breaks away from polar region => past the polar front

.unstable conditions => cloud rising rapidly => heavy rain showers - TS

.cannot predict the exact direction of movement

.life span of several days => 300-1000 NM diameters (average 2-3 days)

.indicate at isohypse high level

.common during seasonal change

.weather activity is usually greatest in afternoon

.Local wind

① Foehn wind => .air uplift by mountain = cools adiabatically (DALR than SALR) = condense and form clouds - precipitates = mountain's upwind slope

.at leeward => air descend = compressed and warm = warm-dry wind

① Windward => .low cloud and precipitation | .leeward => .clear turbulent / no precipitation

. risk of icing

② Chinook = . foehn wind blows on eastern side of Rocky mountains

. blow during the winter ⟶ rapid - considerable rise in temperature

③ Bora => . cold - very dry - gusty katabatic wind

. most strongest - frequent in winter

. blows throughs mountain => direct to Norther Adriatic

. Mistral => . valley wind => . through Rhone valley

. High pressure (Bay of biscay) ⟶ low pressure (Gulf of Genoa)

. increase wind speed due to valley

. cold wind - dry weather - strong wind

Chapter 21

① Geostationary orbit => . circular orbit => located above Equator

. orbit velocity - orbital period => matched the rotation of earth (stationary satellite)

. high altitude orbit => ① Advantage => . wide field of view

② disadvantage => . poor resolution

. monitor the same area / use to monitor location of volcanic ash over large geographical areas

② Polar orbits => . typical altitude = 850km => low orbit

. use to monitor volcanic Ash

. orbit from north - south = passing over both poles

. high resolution / narrow band (1500 NM) sense

. Type of images

① visible light images => . reflected sunlight => seeing basic cloud patterns - storm system ⟶ useful identifying fronts

. dark area = small amounts of light reflected back

. disadvantages => . useful during daylight hours

. difficult to distinguish low clouds - high clouds / snow from clouds

② infrared images => . emitted infrared image => used during day - night

. hot object => appear black | . cold object => appear white

① False colour pictures = . use artificially images ⟶ depict the various temp. range

. help differentiate between the various shade of grey

. ceilometer => . use laser to determine the height of cloud ceiling - cloud base

- Weather radar
- microwave wavelength => 1-10 cm
- detect rain droplets
- reflectivity of precipitation depends => capacity to reflect - diameter of the target

① Airborne weather radar:
- false colour is used => different intensity to return
- attenuation =>
  - absorption - reflection of radars => penetrates an area of precipitation
  - can additional cells that lie behind the first

Ground weather radars =
- pulse - returns system / doppler effect => calculate direction
- indicate area of precipitation - intensity - precipitation

- doppler shift => . change in frequency in the reflected radar signals => by moving precipitation
  - only be used in wet turbulence

Chapter 22

① meteorological service =>
- ICAO = annex 3 => ensure that adequate meteorological information
- WMO => to establish the requirements to fulfill / operational information

- WAFC => . supply with global aeronautical meteorological en-route forecast
  - prepare => . upper - air - gridded forecast - upper air temp and humidity
    - upper wind - FL and temp of tropopause - Cb - CAT

- MWO => . provide information concerning the occurrence - expected occurrence within its area of responsibility
  - prepare sigmet - airmet information
  - prepare airmet

- TCAC => . responsible for the warnings concerning tropical cyclone locations - intensity - movement
  - composed by => regional specialized meteorology centre / tropical cyclone warning centre
  - issue advisory information = . position of cyclone centre - direction - speed of movement

- Volcanic ash advisory centre = . provide the lateral - vertical extent => forecast movement of volcanic ash

② METAR :
- local weather condition at given aerodrome at stated time
- issued every 30 minutes

- wind info =>
  - direction is true
  - mean wind speed taken over 10 minutes
  - gust => . at least 10 kts or more than mean wind
  - variable => wind direction has changed by 60° or more

- visibility =>
  - prevailing visibility => . greatest visibility value which is reached within at least half the horizon circle - surface the A/D
  - RVR => . special measure of visibility in the direction of the rwy
    - reported when visibility below 1500 m / reported in meters - feet (ICAO)
    - highest than prevailing visibility
    - reported in = _ 25 m when RVR 0 - 375 m
      - _ 50 m when RVR 400 - 750 m
      - _ 100 m between RVR 800 - 2000 m =>
        - ① P = RVR is more than maximum reportable value of 1500 m
        - ② U = visibility increase 100 m - more than 10 minutes
        - ③ D = visibility decrease 100 m - more than 10 minutes

- vertical visibility => . issued when sky is obscured => clouds cannot be forecast
  - reported in steps = 30 m (100 ft) up to 600 m (2000 ft)

- cloud base = . measured as height above A/D level ⟶ only report significant convective clouds
- pressure => . QNH (rounded down)
- RE => . significant weather has ceased - reduced in intensity => in the past hour - since last metar was issued
- VC => occurring in the area that lies within radius of 8 km - 16 km of aerodrome reference point
- trend => . valid for 2 hour after observation
  - BECMG => change in the present weather will be long-lasting
  - TEMPO => different conditions prevail for period less than one hour / no more than half the time period

Runway Designator
R27 = Runway 27 or R27L = runway 27 left
R88 = All runways
R99 = A repetition of the last message received because no new information received

Runway Deposits - 1st digit
0 = Clear and dry
1 = Damp
2 = Wet or water patches
3 = Rime or frost covered (depth normally less than 1 mm)
4 = Dry snow
5 = Wet snow
6 = Slush
7 = Ice
8 = Compacted or rolled snow
9 = Frozen ruts or ridges
/ = Type of deposit not reported (e.g. due to runway clearance in progress)

Extent of Runway Contamination - 2nd digit
1 = 10% or less
2 = 11% to 25%
5 = 26% to 50%
9 = 51% to 100%
/ = Not reported (e.g. due to runway clearance in progress)

Depth of Deposit - 3rd & 4th digits
The quoted depth is the mean number of readings or, if operationally significant, the greatest depth measured.
00 = less than 1 mm
01 = 1 mm etc. through to ...
90 = 90 mm
91 = not used
92 = 10 cm
93 = 15 cm
94 = 20 cm
95 = 25 cm
96 = 30 cm
97 = 35 cm
98 = 40 cm or more
99 = Runway(s) non-operational due to snow, slush, ice, large drifts or runway clearance, but depth not reported
// = Depth of deposit operationally not significant or not measurable

Friction Coefficient or Braking Action - 5th & 6th digits
The mean value is transmitted or, if operationally significant, the lowest value.
For example:
28 = Friction coefficient 0.28
35 = Friction coefficient 0.35
or
91 = Braking action: Poor
92 = Braking action: Medium/Poor
93 = Braking action: Medium
94 = Braking action: Medium/Good
95 = Braking action: Good
99 = Figures unreliable (e.g. if equipment has been used which does not measure satisfactorily in slush or loose snow)
// = Braking action not reported

Note 1:
CLRD. If contamination conditions on all runways cease to exist, a group consisting of the code R88/, the abbreviation CLRD, and the Braking Action, is sent.

- SPECI => . special weather report issued = . significant change of the weather
  - changes in = . wind - visibility - duststorm - sand storm - height of cloud base
    - low drifting dust - sand - snow / blowing dust - sand - snow

TAF => forecast of expected conditions

covered => ① not less than 6 hr - not longer than 30 hr | AMD => Amended | CNL = cancelled

TAF less than 12 hr => every 3 hr | COR => corrected

TAF valid for 12 up to 30 => every 6 hr | NIL => missing

Forecast change => ① FM => rapid change in conditions => includes a time to indicate when the change is expected

continues either to the end of current TAF

② BECMG => permanent change in the forecast conditions => at unspecified time within the period

not exceed 2 hr but never be more than 4 hr

anything not included after BECMG => previous forecast for that weather remain in force

③ TEMPO => change in meteorological conditions => occur at any time within specified time period

expect to last less than 1 hr each time => aggregate = no longer than half time period of complete forecast

temporary fluctuation persist longer than 1 hr - aggregate more than half => BECMG would used

④ PROB => indicate the probability of the occurence | followed by BECMG - TEMPO

— prob less than 30% => not considered significant = not reported

— prob 40% => highly likely the weather being forecast will occur

Airmet => warnings for a specified FIR / low-level = up to FL 100 | valid for six hours

description: strong wind - low visibility - TS - significant clouds - moderate icing - turbulence

issued by watch office

SIGMET => detailing significant weather => valid for 4 hr | MTW = ① SEV = > 600 ft/min / MOD = 350-600 ft/min

issued for = thunderstorm - tropical cyclone - turbulence - mountain waves - duststorm

sandstorm - volcanic ash - heavy hail - radioactive cloud

crew issued special air-reports ⟶ source of information for MWO => preparing SIGMET

① Volcanic sigmet => 9 VAAC => operate by national meteorological service

detecting volcanic ash clouds => tracking future movement of the clouds

② Tropical sigmet => 6 regional centres

monitor - track - advise on TRS within their areas

Aerodrome warning = issued by A/D meteorological office

give information of meteorological condition => affect A/C on ground - facilities - service

issued for = gales - strong wind (exceeding 28 kt - 34 kt) - TS - hail - squalls - snow (include accumulation)

frost warnings - fog - freezing precipitation - duststorms - sandstorm - tsunami - volcanic ash

Volmet => broadcast of ground-to-air radio => HF - VHF

provide most recent METAR - TAF - Sigmet for various A/D

① on VHF => contain information METAR - SPECI - TREND

② on HF => METAR - speci - TREND - TAF - SIGMET

Atis => current - routine information arriving - departing

throughout 24 hrs

Gamet => message of forecast about meteorological condition

area forecast for low level

Windshear warnings - alerts: designed by meteorological authority of A/D

give => information observed - expected of windshear

affect => App path - T/O path - circling app (two level - 1600 ft) - landing - T/O roll

Routine air-reports => routine observations with regional air navigation every 15 min

during climb-out => every 30 second for first 10 min

Special air-reports = issued => moderate or severe turbulence - icing - heavy dust storm - heavy sandstorm

severe mountain wave - TS (OBSC - EMBD - SQ) - hail - volcanic ash cloud

valuable sources of information for MWO

Significant weather chart

— produced by world area forecast | produced daily at 6 hr intervals => 00Z - 06Z - 12Z - 18Z

measure altitude between 10 000 - 63 000 ft | high level => from FL 250 - 630 / medium level: FL 100 - 450

① valid for a specific time - specific areas (UTC time)

② forecast of expected conditions

Jet stream => FL 320 | 220/400 => flight levels between the wind equal - excess of 80 kts

put when the core speed is equal or excess 80 kts

maximum speed (core)

jet change speed by ± 20 kts / jet core change ± 3000 ft

clouds: only CBs are reported

XXX => top or base of cloud => outside the area of chart

ISOL, (Isolated): individual
OCNL, (Occasional): well separated
FRQ, (Frequent): little or no separation between CB
SQL, (Squall): a line of CB with little or no separation

Symbols for Significant Weather			
	Tropical Cyclone		Drizzle
	Severe Squall Line*		Rain
	Moderate Turbulence		Snow
	Severe Turbulence		Shower / Hail
	Mountain Waves		Widespread Blowing Snow
	Moderate Aircraft Icing		Severe sand or Dust Haze
	Severe Aircraft Icing		Severe Sandrtorm or Duststorm
	Widespread Fog		Widespread Haze
	Radioactive Materials in the Atmosphere**		Widespread Mist
	Volcanic Eruption***		Widespread Smoke
	Mountain Obscuration		Freezing Precipitation****

Numerical Weather Prediction (NWP)

To run numerical weather prediction models, meteorologists divide the Earth's surface and atmosphere into a 3D grid called a global coordinate system. All weather data are mapped onto this grid with each grid box representing the atmospheric processes in that region. Atmospheric models can calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions within neighbouring points. Numerical prediction equations are applied to each box of the grid and across an aggregation of medium-range weather forecast some two to fifteen days ahead.

- The 3D grid consists of horizontal data (latitude-longitude) and vertical data (height or pressure).

a) obscured (OBSC) if it is observed by haze or smoke or cannot be really seen due to darkness;
b) embedded (EMBD) if it is embedded within cloud layers and cannot be readily recognized;
c) isolated (ISOL) if it consists of individual features which affect, or are forecast to affect, an area with a maximum spatial coverage less than 50 per cent of the area concerned (at a fixed time or during the period of validity); and
d) **occasional (OCNL)** if it consists of **well-separated features** which affect, or are forecast to affect, an area with a maximum spatial coverage between 50 and 75 per cent of the area concerned (at a fixed time or during the period of validity).