CPL Theory Meteorology (CMET)

CAE Oxford Aviation Academy

CMET 5 – Clouds & Precipitation

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CMET 5 – Clouds & Precipitation

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes

CLOUD FORMS

Cloud Forms

- Clouds are groups of tiny water droplets suspended in the atmosphere

- They can exist in a variety of shapes and sizes. Some basic classifications include:

Stratiform

- Large horizontal extent – forms a sheet or layer of cloud

Cumuliform

- Heaped or clumped – the stereotypical “cloud”

- Can have significant vertical extent

Nimbus

- These clouds will have accompanying precipitation in the form of rain or showers

Cirriform

- Very fine, wispy cloud

- Often described as “threadlike” or “hairy”

Cloud Forms

- These 4 general classifications can be combined to distinguish the **10 genera cloud forms**

- We may also classify clouds according to the **height of the cloud base**:

High Etage (High Level Cloud)
- Cirrus
- Cirrostratus
- Cirrocumulus

} **20,000ft to 40,000ft bases**

Middle Etage (Medium Level Cloud)
- Altostratus
- Altocumulus

} **8,500ft to 20,000ft bases**

Low Etage (Low Level Cloud)
- Nimbostratus (may be up to 20,000')
- Cumulonimbus
- Cumulus
- Stratocumulus
- Stratus

} **500ft to 8,500ft bases**

High Etage – Cirrus (Ci)

Appearance:

- Detached clouds
- White delicate filaments
- Fibrous or silky
- Composed of ice crystals

Associated Weather:

- Nil precipitation
- Nil turbulence
- Nil icing

High Etage – Cirrostratus (Cs)

Appearance:

- Transparent whitish veil of fibrous or smooth appearance
- May produce the "halo phenomena"
- Totally or partly covers the sky
- Composed of ice crystals

Associated Weather:

- Nil precipitation
- Nil turbulence
- Nil icing

High Etage – Cirrocumulus (Cc)

Appearance:

- Thin patches or clumps of cirrus
- May form “ripples”
- Composed of ice crystals

Associated Weather:

- Nil precipitation
- Nil turbulence
- Nil icing

Middle Etage – Altostratus (As)

Appearance:

- Greyish or bluish sheet
- Sun appears as though looking through ground glass

Associated Weather:

- Rain/snow
- Virga
- Little to light turbulence
- Light-Moderate Rime Ice
- Clear Ice possible in lower layers of thick altostratus

Middle Etage – Altocumulus (Ac)

Appearance:

- White/grey clumps

Associated Weather:

- Nil precipitation
- Light turbulence
- Nil – Light Rime Ice

Low Etage – Nimbostratus (Ns)

Appearance:

- Dark grey sheet or layer
- Obscures the sun

Associated Weather:

- Heavy continuous rain or snow
- Generally light but may be moderate – severe at fronts or over highlands
- Moderate Rime Ice
- Clear Ice probable in lower levels

Low Etage – Cumulonimbus (Cb)

Appearance:

- Cellular/heaped
- Very large vertical extent
- Top may appear “anvil shaped”

Associated Weather:

- Thunderstorms
- Showers of rain/snow/hail
- Lightning/Thunder
- Severe Turbulence
- Severe Clear Ice

Low Etage – Cumulus (Cu)

Appearance:

- Cellular/clumpy
- Cauliflower shaped

Associated Weather:

- Nil precipitation
- Light to moderate turbulence
- Little icing risk

Low Etage – Stratocumulus (Sc)

Appearance:

- A sheet of clumpy/cellular cloud

Associated Weather:

- Drizzle
- Light to moderate turbulence
- Occasional Rime Ice

Low Etage – Stratus (St)

Appearance:

- Greyish thin sheet or layer

Associated Weather:

- Maybe drizzle
- Light turbulence
- Usually nil icing

Refer to Bureau of Meteorology's "Manual of Aviation Meteorology" pp 45-46

You will need to learn this table!

CLOUD FORMATION

Cloud Formation

- We already know that cloud formation requires the cooling of moist air until saturation
- The most efficient way to cool air is by lifting it to higher altitudes
- Cloud formation is therefore categorised into the methods of ascent:

1. Convection

2. Convergence

3. Orographic Uplift

4. Turbulence/Mixing

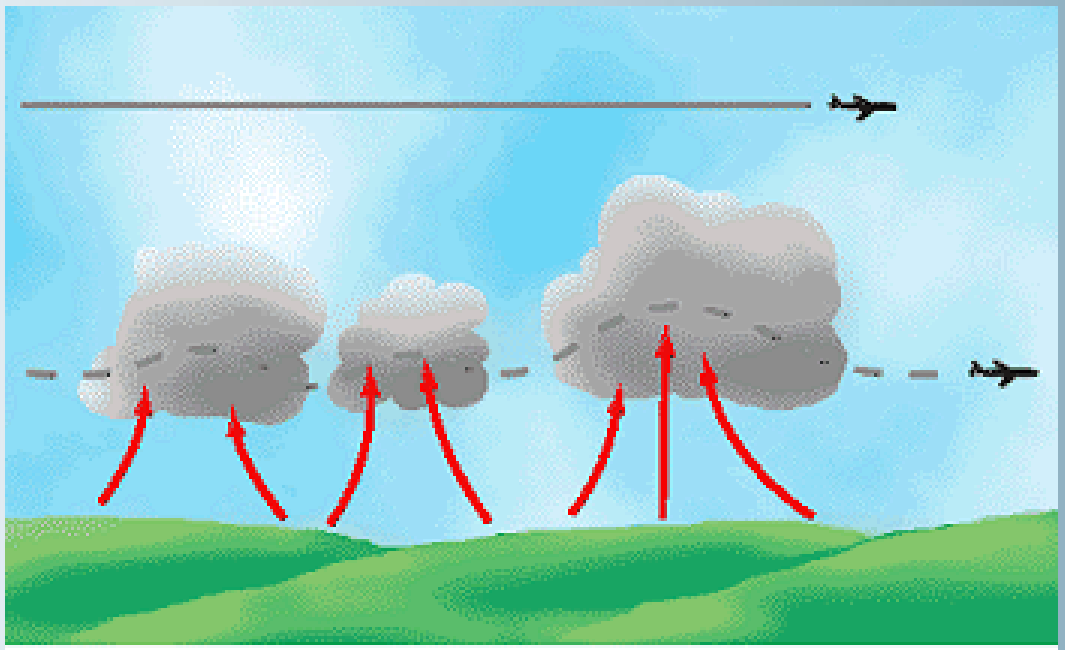
5. Widespread Ascent

6. Latitudinal heating

Cloud Formation - Convection

- When air is heated by a warm surface, it will rise
- The air ascends and cools adiabatically to its dew point temperature, after which clouds will form
- Convection is likely to produce **Cumuliform Cloud**

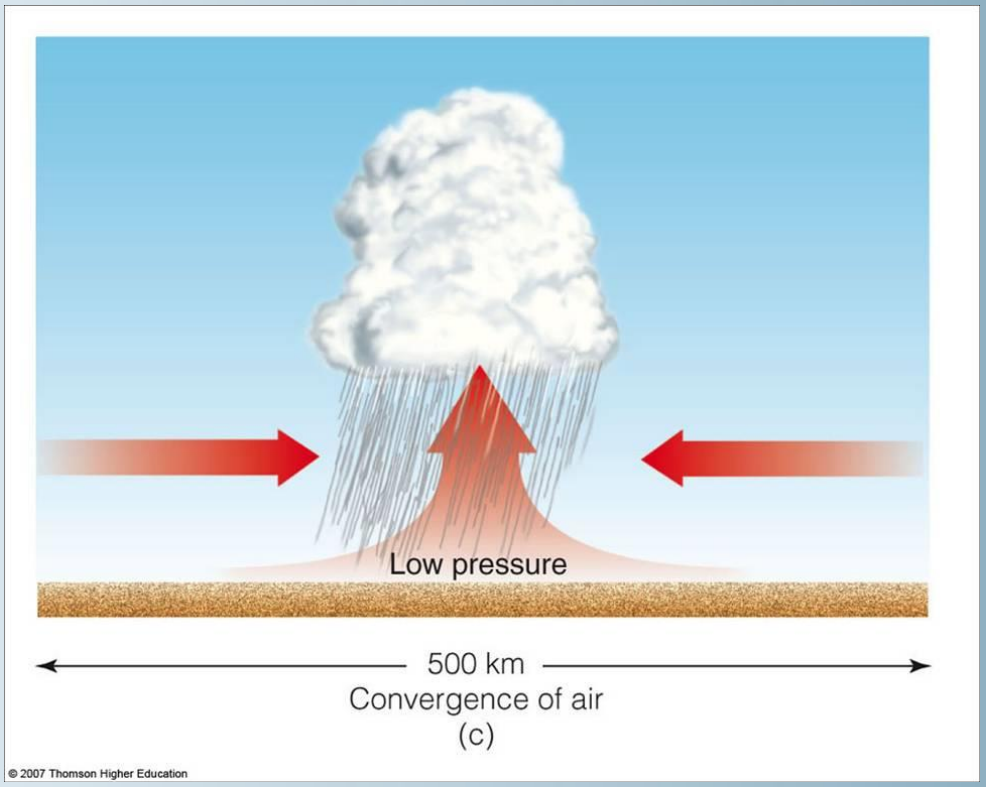
Air warmed from below



Aircraft can avoid turbulence from convective clouds by flying above the clouds

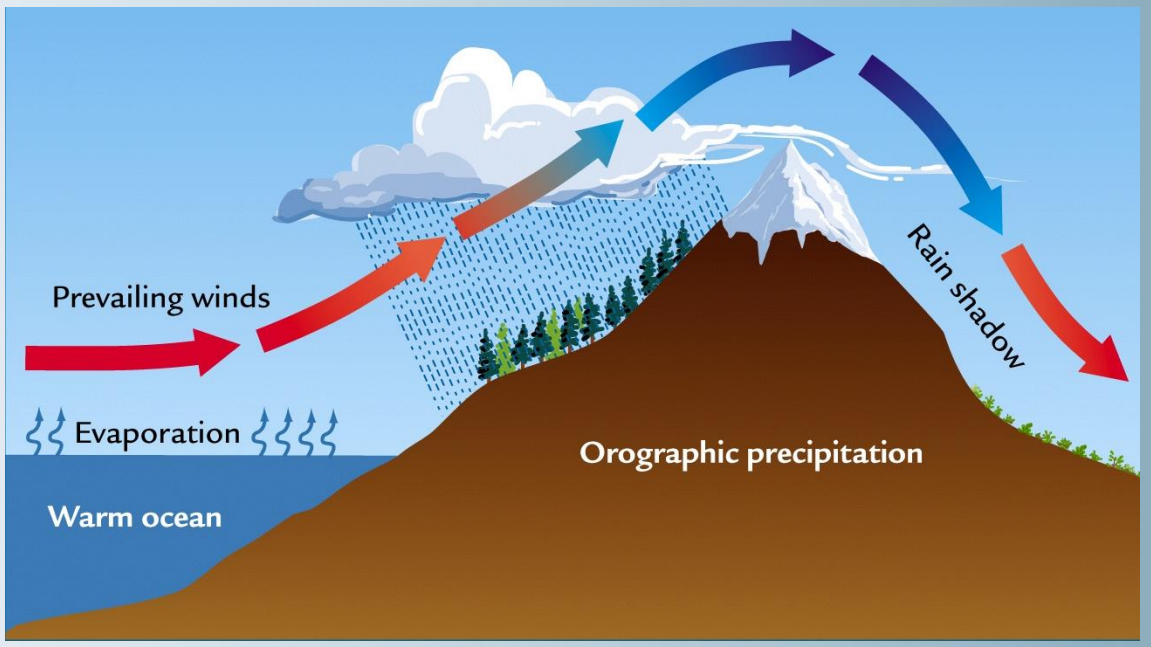
Cloud Formation – Convergence

- As two airstream converge, they have nowhere to go but up, causing convection and possibly cloud
- Convergence occurs in low pressure systems such as the equatorial
- It occurs in areas such as the equatorial trough and sub polar low
- Produces slow, widespread ascent with widespread cloud



Cloud Formation – Orographic Uplift

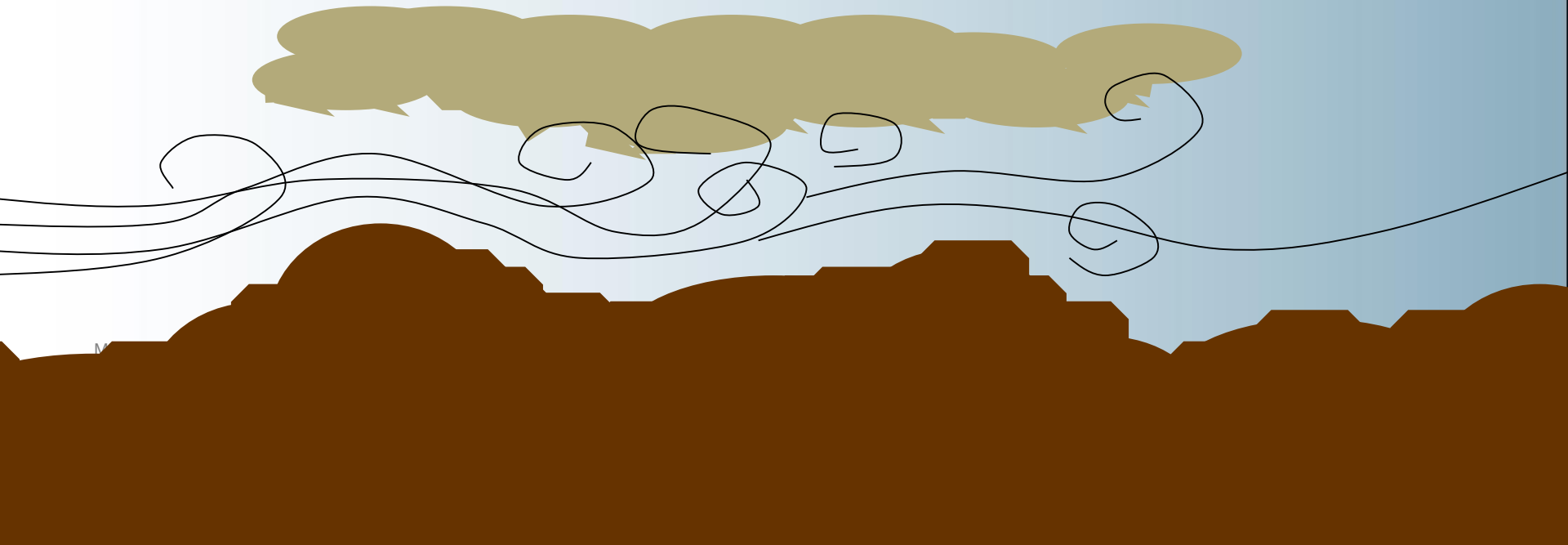
- Moist air is **forced to rise due to the shape of the terrain**
- As it rises, it will cool adiabatically and may condense to form cloud
- Precipitation will often occur on the **wind-ward side of the mountain**



- As the air reaches the lee-ward side of the mountain, most of its moisture has already been lost, resulting in a **dry, down-sloping flow of air**
- This may produce areas of desert/sparse land known as **“rain-shadow deserts”**

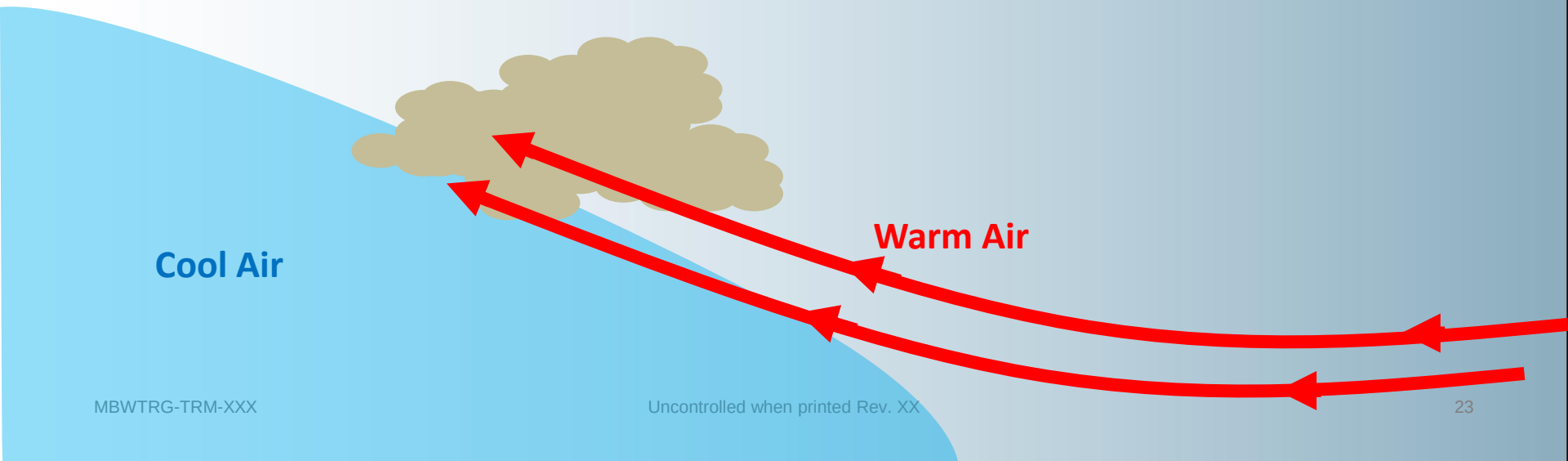
Cloud Formation – Turbulence/Mixing

- As air flows over the ground, **surface friction causes variation in wind velocity**
- This may produce **eddies** which cause the lower levels of air to mix
- The air in the rising currents of turbulence will cool and may become saturated, at which point the air will condense to form cloud
- This is most likely to produce **Stratus** or **Stratocumulus Cloud**



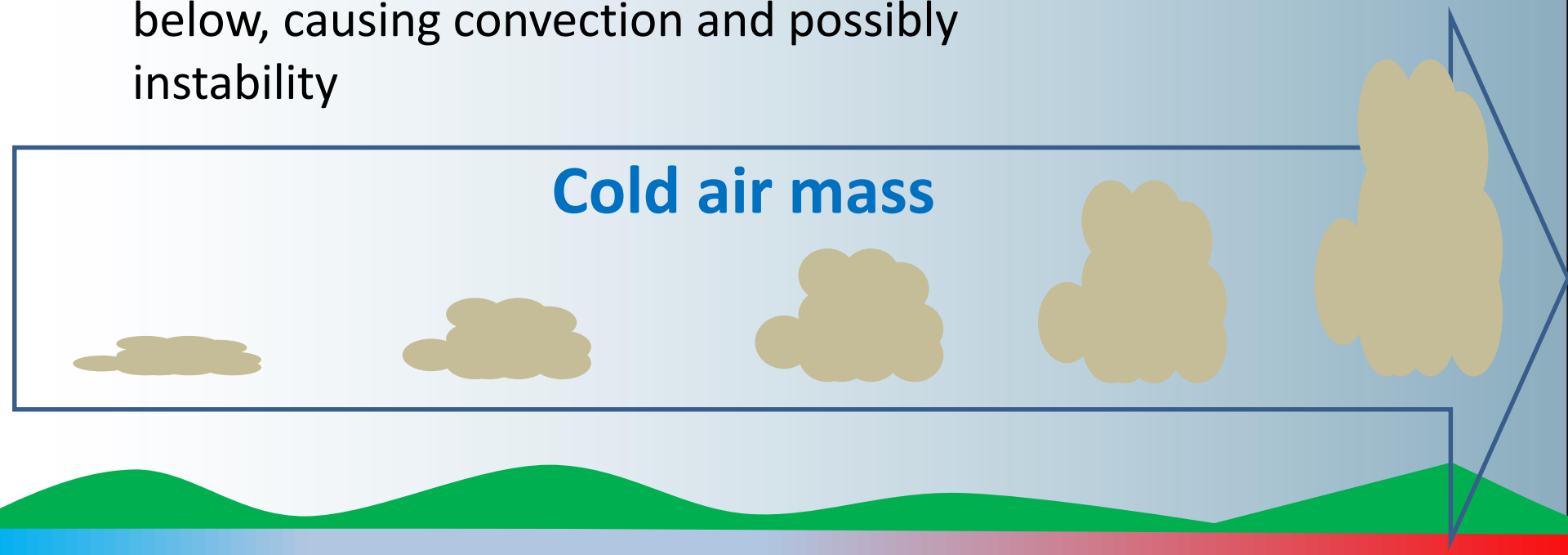
Cloud Formation – Widespread Ascent

- This is simply ascent due to the presence of a **front**
- When cold air and warm air meet, the less-dense warm air will slide up and over the top of the cooler air
- This rising warm air will now cool adiabatically and may condense to form cloud



Cloud Formation – Latitudinal heating

- Cold air mass moving north is warmed from below, causing convection and possibly instability



South –
Cold terrain

North –
Warmer terrain

PRECIPITATION

Precipitation

"Liquid or solid particles falling and reaching the ground"

- Precipitation includes the following:

1. Drizzle (DZ)

2. Rain (RA)

3. Showers (SH)

4. Snow (SN)

5. Hail (GR)

6. Ice Pellets (PL)

7. Soft Hail, Graupel & Snow Pellets (GS)

Precipitation

"Liquid or solid particles falling and reaching the ground"

Drizzle (DZ)

- Very fine water droplets – smaller in size than raindrops
- Falls from a continuous and dense layer of low **Stratiform Cloud**

Rain (RA)

- Larger water droplets than drizzle
- Falls from **Stratiform Cloud**

Freezing Rain (FZRA)

- **Super-cooled liquid** droplets
- They will **freeze on contact** with cold surfaces e.g. an aircraft in flight

Precipitation

"Liquid or solid particles falling and reaching the ground"

Snow (SN)

- Ice crystals that have joined together to form "snowflakes"

Hail (GR)

- Ice stones with varying diameters

Ice Pellets (PL)

- Partially frozen rain drops
- The interior may still be liquid

Soft Hail, Graupel & Snow Pellets (GS)

- A central ice crystal is surrounded by frozen water droplets

Precipitation

Intermittent Precipitation

- Falls from **stratiform** (but not cumuliform) cloud.
- Lasts for periods of **up to 50 minutes in any one recording hour**.
- The cloud cover itself will be near overcast although its thickness may vary considerably so that the sky appears to brighten - cloud breaks of varying duration may occur.
- Cloud base usually lowers when the Precipitation is falling.

INTERMITTENT DRIZZLE	**(DZ)**	From **St**, possibly **Sc**.
INTERMITTENT RAIN	**(RA)**	From **Sc, As**.
INTERMITTENT SNOW	**(SN)**	From **As**

Precipitation

Continuous Precipitation

- Falls from **stratiform cloud**, lasts for periods for **more than 50 minutes in any one recording hour**.

- The dense cloud layer may have a well defined base but there will not be any noticeable clearing or brightening of the sky.

CONTINUOUS DRIZZLE	**(DZ)**	From St
CONTINUOUS RAIN OR SNOW	**(RA,SN)**	From Ns, possibly thick As

Precipitation

"Liquid or solid particles falling and reaching the ground"

Showers (SH)

- May consist of **water drops (RASH)**, **hail (GRSH)** or **snow (SNSH)**
- Falls from **Cumuliform Cloud (Cu)**
- Unlike rain, showers have an **abrupt start and finish** and their **intensity varies**
- Usually **last 15 – 30 mins**

HAIL SHOWERS	**(GRSH)**	From **Cb**
RAIN SHOWERS	**(RASH)**	From **Cb, TCu**, possibly from **Ac**
SNOW SHOWERS	**(SNSH)**	From **Cb, TCu**, possibly from **Ac**

Other Forms of Moisture

- Not all forms of moisture in the atmosphere are considered to be precipitation

Dew/Frost

- Water droplets formed by condensation of water vapour on the ground
- Since they do not fall to the ground, they are not considered precipitation

Virga

- Not all raindrops/ice crystals reach the ground when they fall
- Sometimes, the moisture may be re-evaporated back into the atmosphere
- **Virga is rain that does not hit the ground**

CLOUD DISPERSAL

Cloud Dispersal

Insolation

- Solar radiation will increase the surface temperature which will in turn heat the air
- Warmer air can hold more water vapour, so cloud may evaporate – “burning off”

Subsidence

- As cloud descends, the surrounding air becomes warmer and clouds may evaporate

Precipitation

- Precipitation removes moisture from inside the cloud
- Eventually, the moisture content reduces to a point below saturation and the remaining liquid particles will evaporate into the air

Mixing with Drier Air

- Turbulence causes mixing of the air inside the cloud with that outside the cloud
- If the outside air is unsaturated, this mixing will cause cloud erosion

FOG

Fog

- What is the difference between fog and cloud?

- Fog is simply **cloud on the ground**

Fog

- All fog will form via one basic process:

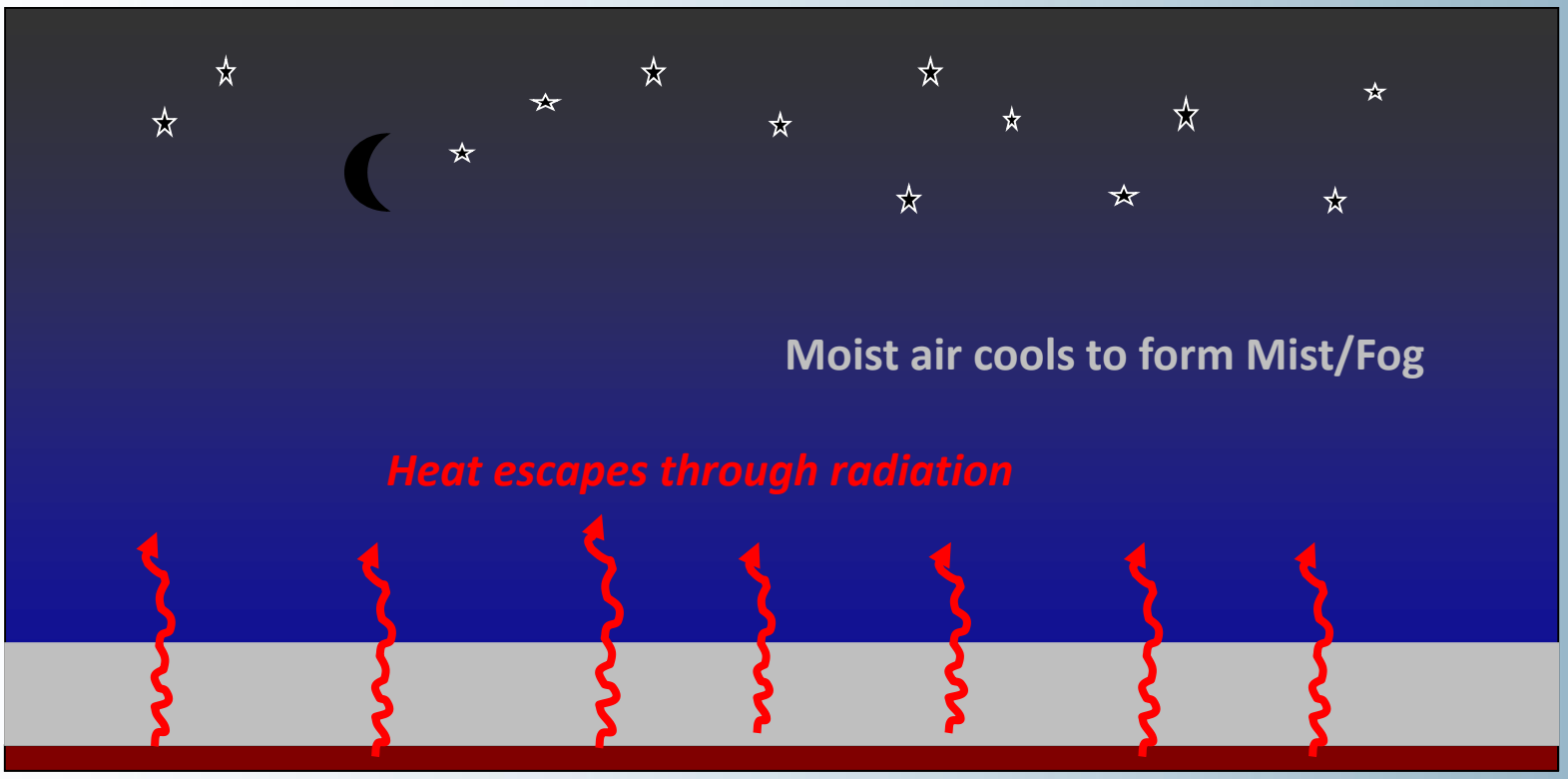
"Moist air is cooled by an underlying cold surface to a temperature below saturation point"

- Fog is often classified according to the cause of the above process:

1. **Radiation Fog**
2. **Advection Fog**
3. **Steam Fog**
4. **Frontal Fog**
5. **Sea Fog**
6. **Upslope Fog**

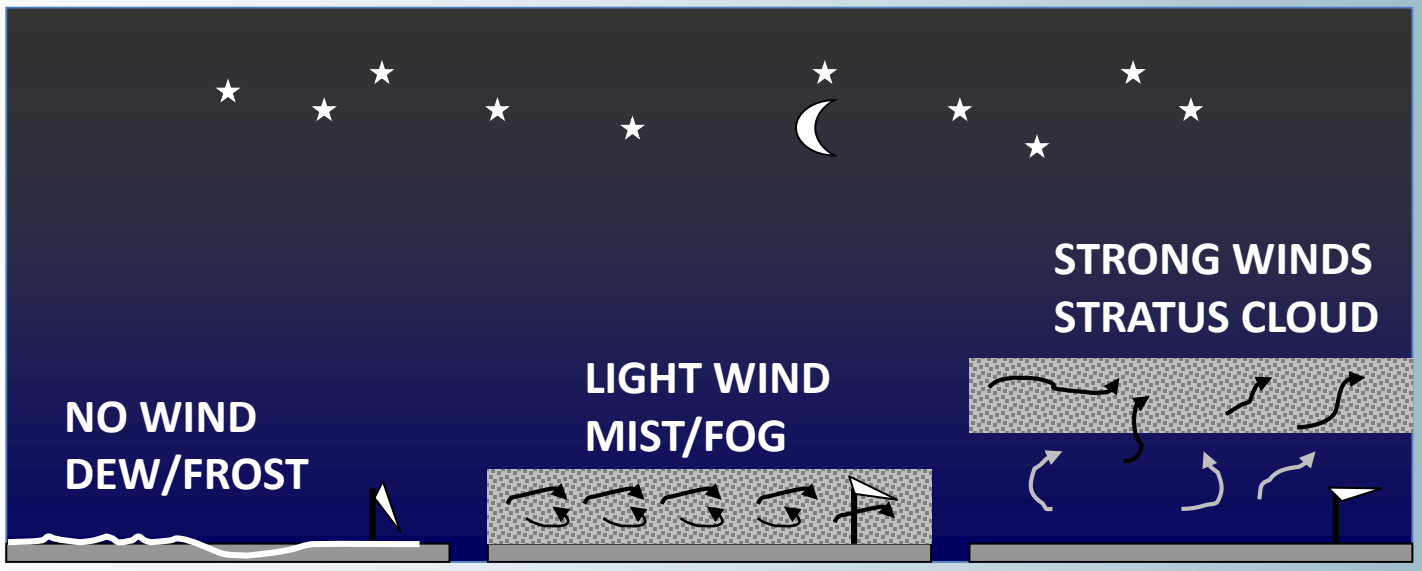
Radiation Fog – How does it form?

- At night, the earth cools via **terrestrial radiation**
- This causes the air just above the surface to cool via **conduction**
- If the air cools to below dew point, moisture in the air will condense to form **fog**



Radiation Fog – What are the necessary conditions?

- **Clear skies at night time** – to allow large heat loss at the surface
- **Cool surface temperatures** – little further cooling will be required for saturation
- **A high moisture content** – little further cooling will be required for saturation
- **Light winds (5-7 knots)** – light winds will increase the thickness of the fog layer
- These conditions are most likely in a **High Pressure System** (Anticyclone)



Radiation Fog – How does it affect us?

- Reduces visibility – especially in valleys as the **denser colder air will sink** into them

- The international standards for visibility define fog as:

FOG

Visibility less than 1000m

MIST

1000m < Visibility < 2000m

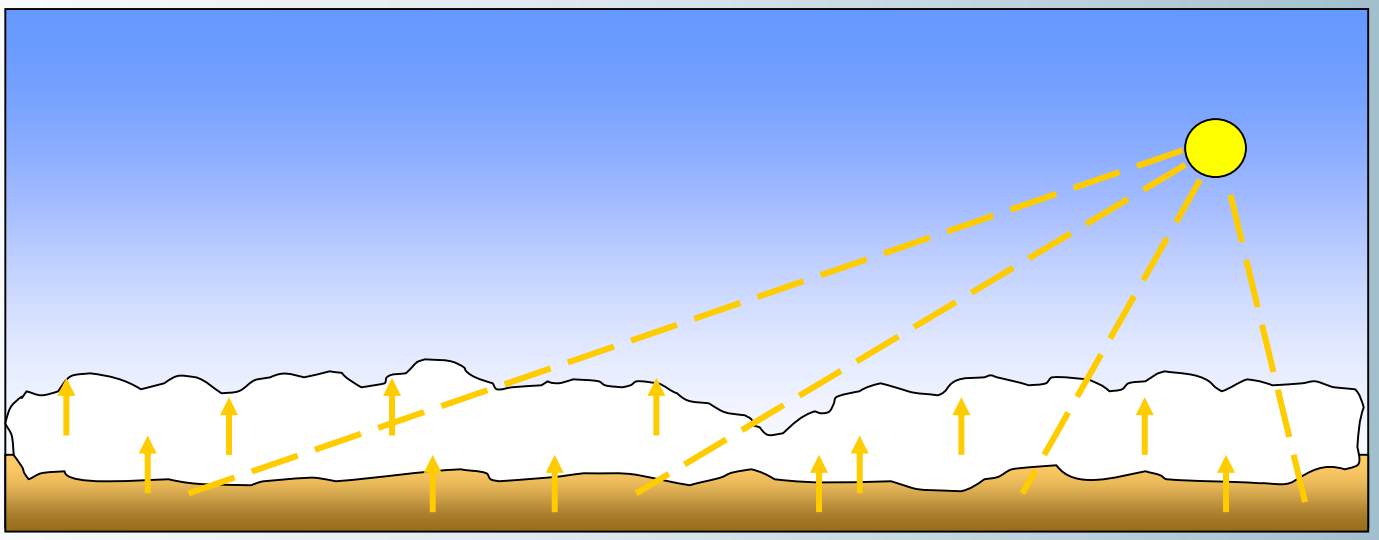
HAZE

2000m < Visibility < 5000m

Radiation Fog – How does it dissipate?

1. Increase in Temperature

- Radiation Fog usually disperses a few hours after sunrise

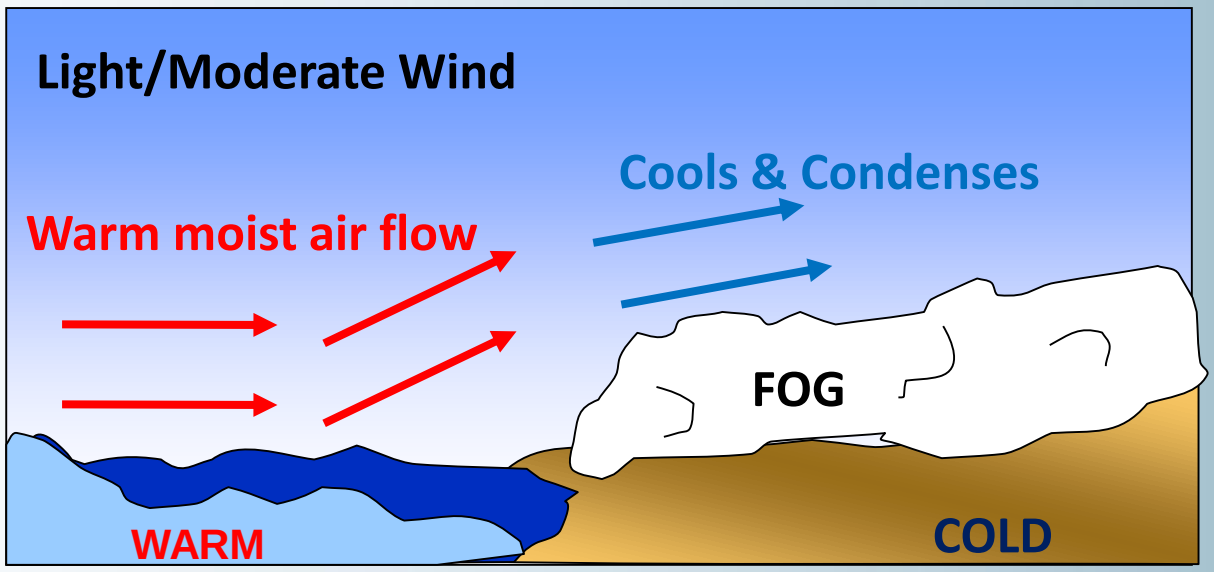


2. Increase in wind strength

- An increase in wind strength above a light wind will disperse the fog
- It may also lift and form low stratus cloud

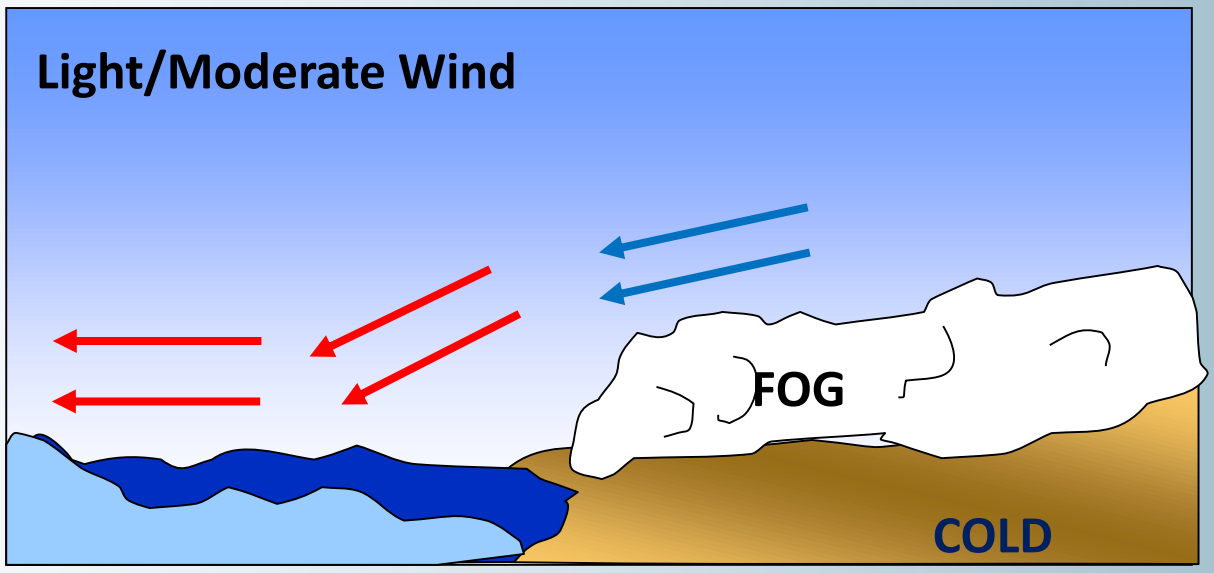
Advection Fog – How does it form?

- Air will adopt the characteristics of the surface below it
- Air over a warm ocean becomes warm
- If that warm air is blown over a cooler surface, it will also become cool
- As it cools, it may condense to form fog



Advection Fog – How does it dissipate?

- Advection refers horizontal movement of air
- Advection Fog forms due to the **wind direction** of that airflow – blowing warm air over a cooler surface
- If the wind direction changes, the formation of advection fog will no longer occur



Sea Fog

- Sea Fog is simply Advection Fog where either:

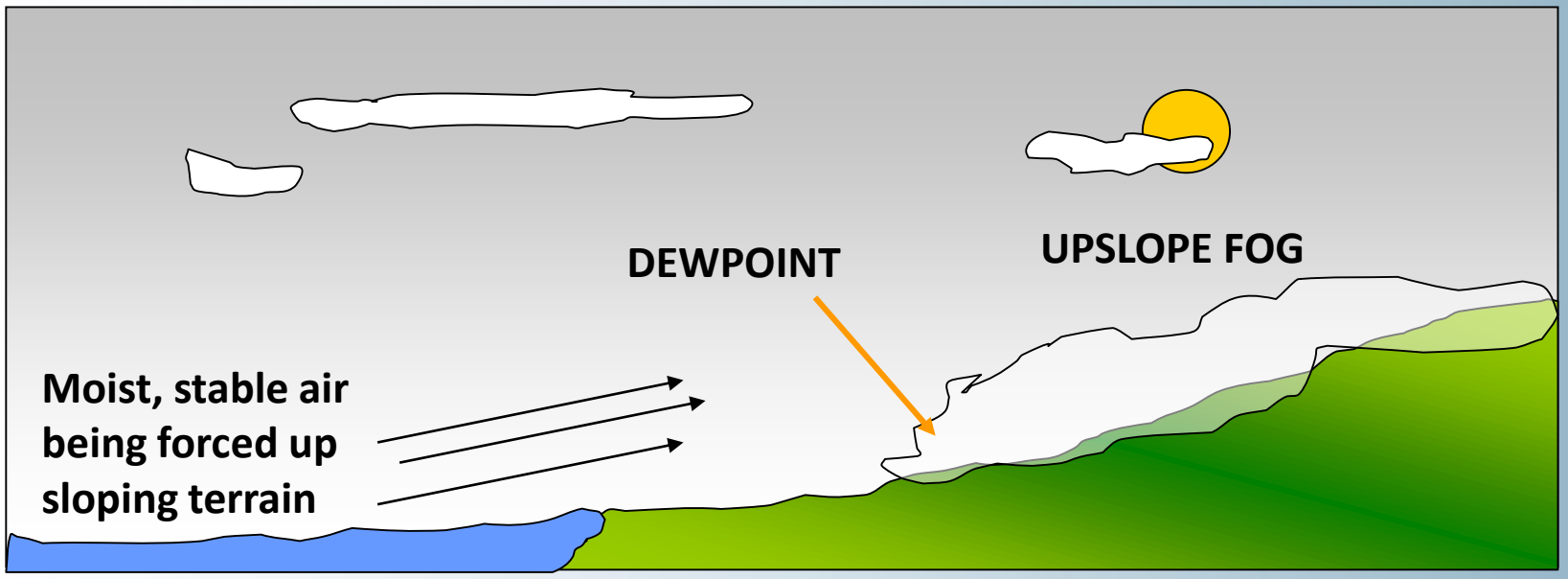
1. **Warm moist air over a warm ocean moves to an area of cooler ocean** – e.g. tropical maritime air moving towards the poles

2. **Warm moist air over a warm land surface moves to an area of cooler ocean**

- They are rare in Australia but are often widespread and persistent even in moderate winds – they have been known to last up to several days

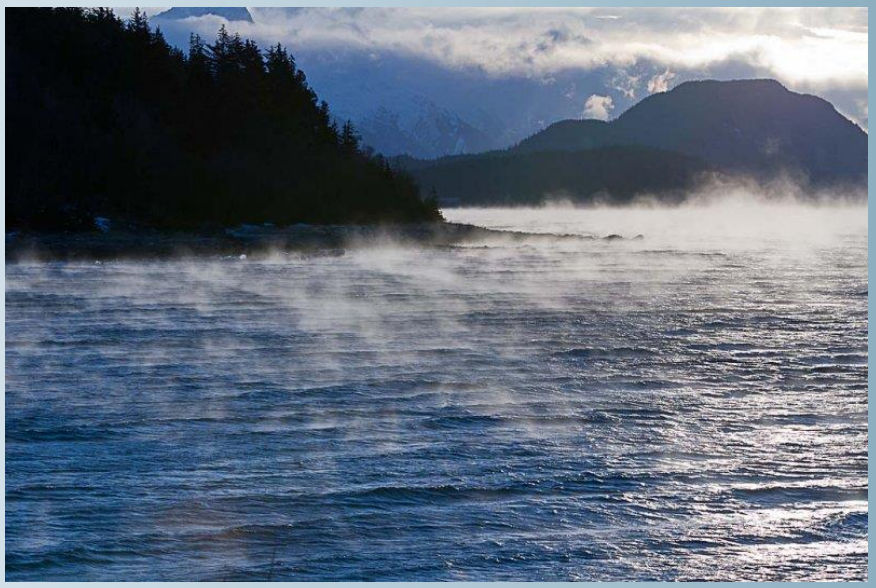
Upslope Fog

- When moist air is force up a terrain slope, it will cool adiabatically and may form fog
- This is a similar process to the formation of cloud by orographic lifting
- Upslope Fog is common on high ground close to the coast whenever an on-shore wind is blowing
- If the on-shore wind ceases, the fog will dissipate

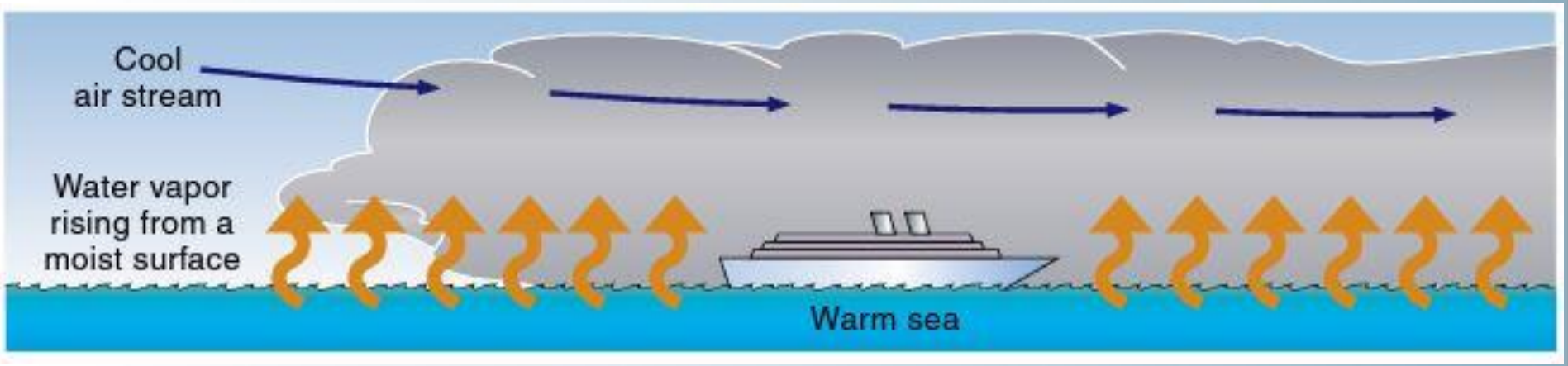


Steam Fog

- Forms when cool air blows over a warm, moist surface (sea or land)
- Evaporation of the moisture from the warm surface will quickly be cooled by the cool air and will condense to form fog
- The cool air must be 10° C colder than the surface

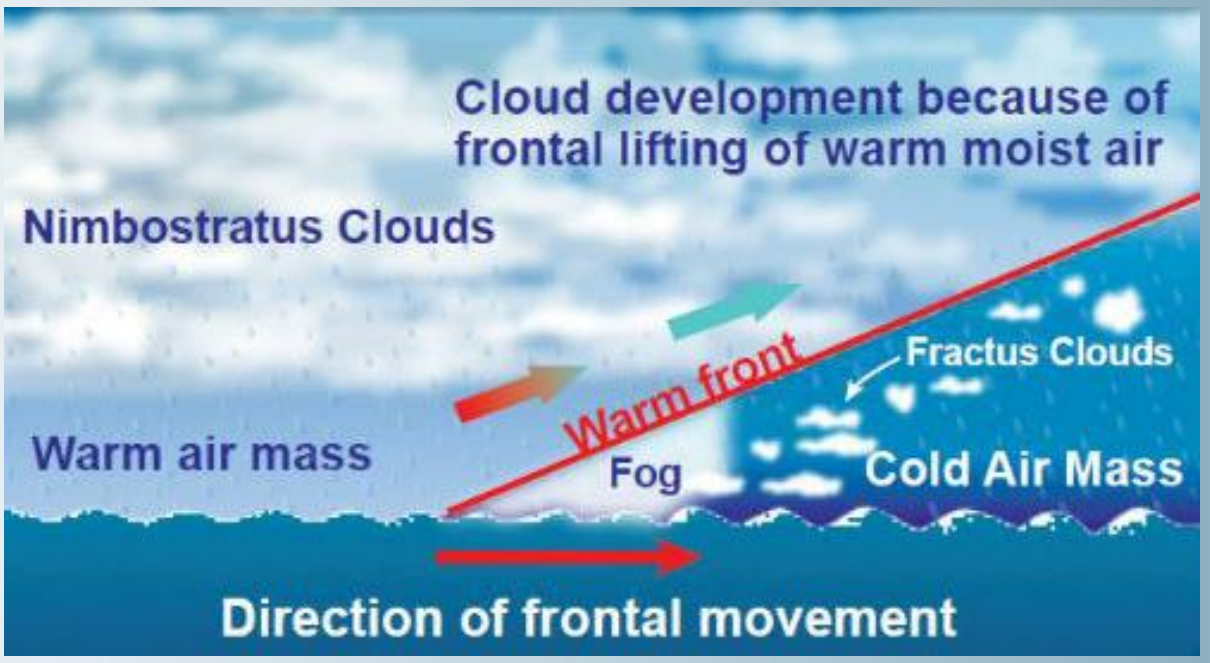


- Also known as Arctic Sea Smoke, it can be very thick and widespread



Frontal Fog

- Usually occurs in a Warm Front - a warm air mass is moving into an area of cooler air



- Warm precipitation from cloud descends through the front into the cooler air
- The falling precipitation may increase the humidity of the cooler air mass to saturation and fog will form
- Also known as rain-fog, this will occur quite rapidly and will be quite extensive
- Often hard to distinguish the fog due to other poor weather and dense low cloud