Condensation and Precipitation

Lecture 4

HUMIDITY, PRECIPITATION AND CLOUDS



Air is formed of 99% nitrogen and air, the rest being trace gases such as argon, CO2 and water vapour.

The amount of water vapour is called humidity.

The amount of water vapour that can be held by air depends on the temperature.

The actual amount of vapour held in air is called absolute humidity (in gm per kg of air).
The % that this forms of the capacity of the air to hold vapour is called relative humidity.

Points A 1-5 are all at 100% relative humidity. B3 is 80%, C3 is 33%, M is 50%.

For air at temperature and humidity of B3, C3 and M to reach saturation (100% relative humidity) it must either

ADD WATER VAPOUR

OR

BE COOLED

- H2O can exist in solid, liquid, or gaseous states.
- Change from liquid to gas is evaporation.
 Change from gas to liquid is condensation.
 Change to/from the solid to gas is sublimation.
- Evaporation occurs where water is plentiful (over oceans, water and transpiring vegetation)
- Condensation occurs where the relative humidity 100% (saturation) which occurs when evaporation is rapid or where the air is cooled.
- Rapid evaporation occurs over water or forests.

AIR COOLING occurs by:

- 1. Mixing with cooler air
- 2. Contact with cold surface
- 3. Movement (advection) over colder ground
- 4. Lifting of air up through the atmosphere

Over oceans, evaporation is likely to exceed Ppt. Over land, Ppt is likely to exceed evaporation.

- **E** Evaporation
- **T** Transpiration
- C Condensation Ppt - Precipitation





When air is saturated, the rate of evaporation equals condensation





MIXING

Condensation may occur when warmer and cooler air masses mix together at their margins





Zone of mixing warmer air cooled and relative humidity rises; when humidity reaches 100%, condensation occurs on particles and clouds form.

Mixing of air along a front betwen two air masses results in clouds along the front



Ground level condensation may occur due to movement of warmer air across a cooler surface (this may be land or sea). This lateral movement of air is called **ADVECTION**.

Air is warmed by contact with milder Atlantic ocean in January, increases humidity to 100% Mild, humid air cools by contact with cold land surface; relative humidity increases; condensation occurs on surfaces (ground and particles in the air)

Atlantic Ocean in January is warmer than air (water retains heat better than land). Britain in January is cold land loses heat more rapidly than the ocean

ADVECTION FOG

Here, warm air from the land is cooled when it passes over colder water (in summer, usually). Sea fogs are produced in this way, when air above warmer water moves across colder water and is cooled.





Cold surfaces are common in mountains, where snow reflects solar radiation and remains cold, cooling air in contact with the ground.







COOLING OF AIR - 2 and 3

Frost froming under clear skies which aid radiation cooling of the ground



The most available surface is the ground itself, or the vegetation. This is called **dew**. If dew freezes, **frost** is formed. If dew point temperature is below 0°C, vapour changes directly into ice, forming hoar frost. Excessive hu



Excessive humidity or many particles in the air cause fog, when condensation occurs on particles in the air. This is common in cities where pollution produces particles - producing smog

Dew

(smoke & fog).



Both radiation and advection cooling result in cooling of air at ground level. If the air is cooled below its dew point temperature, condensation of the water vapour held by the air may take place on any surfaces available.

Solid ice also forms when water on the surface freezes; this is not frost, though frost may add to it.





Icicles - a combination of freezing and frost





UPLIFT OF AIR IS ESSENTIAL FOR CLOUD FORMATION AND RAINFALL

There are 4 mechanisms which may cause the uplift of air.

ASCENT

- When air is lifted up through the atmosphere it cools at 0.6°C per 100m
- It cools due to decompression because air is less dense at higher altitudes.
- Cooling causes relative humidity to rise
 (cooler air can hold less water vapour).
- If air cools to dew point temperature, condensation occurs on any available surfaces at altitude, this can only be particles in the air (or aeroplanes etc)
- Such particles are essential for condensation, and come from volcanic dust, sea salt from evaporated spray etc
- Some, eg salt, attract water (hygroscopic nucleii) and form clouds easily.
- **Clouds** form from such condensation. They re simply countless billions of water droplets or ice crystals too light to fall to ground. Whether ice or water depends on the altitude and temperature.
- Precipitation may occur if uplift continues

RISING AIR and CLOUD FORMATION

Cloud formation continues as high as air rises. When air stops rising, cloud development stops. The more uplift, the taller and deeper the clouds

Relative humidity reaches 100%
(saturation) at dew point temperature.
Water vapour starts to condense on particles above this level - cloud base level.
Saturated air cools more slowly than 0.6°C per 100m, making it more likely to continue to rise (unstable) and produce deeper clouds

Rising air expands with less pressure at altitude. This causes cooling, which causes relative humidity to rise. Air continues to rise as long as it is forced upwards, or surrounding air is NOT as warm as the rising air.



CLOUD BASE







CLOUD FORMATION

The size and shape of clouds depends entirely on the amountof uplift of the air. The altitude of cloud base depends on thealtitude of the condensation level ie the altitude at whichcooling air reaches dew point temperature (saturation, or100% relative humidity)Here, uplift is so strong

Here, uplift is so strong that the cloud is very deep, and rainfall occurs.



Cloud base is constant across a wide area, as any of the air mass (constant in temperature and relative humidity) reaches dew point at the same altitude - about a 1000m?

LIMITED UPLIFT CAUSES SHALLOW CLOUDS

CLOUD BASE at CONDENSATION LEVEL

UPLIFT CONTINUES

Below, a forest fire has caused a cloud (not just smoke) due partly to the heat casuing convection, but mainly to the increased number of ash particles which increase the rate of condensation.



Atmospheric Lifting Mechanisms

Air Lifting processes create clouds & precipitation Are the only means of precipitation on Earth Four types of lifting are recognized:

Orographic Lifting
 Convectional Lifting
 Frontal Lifting
 Convergence





Westerly winds blow humid air onshore from the Atlantic Ocean Air sinks down on leeside of high land, contracts due to denser air, warms up, relative humidity falls and rainfall diminishes. This results in an area of lower rainfall, called a rain shadow. An example is lowland to the east of Britain, such as East Anglia.



WHY AIR RISES (2) - CONVECTION



WHY AIR RISES (3) - FRONTAL



Convectional Lifting

- Anywhere air is warmer than its surrounding air, it will rise.
- In this example an island heats more than the surrounding water and causes a massive cumulus cloud to form.



Convectional Lifting in the Desert

Extremely high afternoon temperatures in late summer often leads to thunderstorms throughout the world's arid regions.





Mojave Desert

The Grand Canyon in August

Frontal Lifting of Air

Although not a mountain range, masses of moving air Create the same effect – Unlike mountains air masses Can provide lifting in many different locations

Fronts can lift air Which is stable, Creating clouds & large amounts Of precipitation As rain, snow, Sleet or hail



Precipitation Types / Properties

Snow

Sleet









Snowflakes and Temperature







Convergence



Convergence occurs when large air masses meet & are forced to rise vertically by crowding of molecules.

This process is best seen at the ITCZ where the Trades Winds meet & rise to form towering clouds & heavy precipitation The shape and depth of clouds depend on the temperature and humidity of the air, and the degree of uplift to which it is subjected.







CLOUD TYPES

CONVECTIONAL UPLIFT results in cumulus clouds. If uplift is continued, then they develop vertically to become storm clouds; cumulo-nimbus which only spread out laterally at the tropopause (about 12km).

CIRRUS clouds are thin, wispy clouds formed from ice crystals at high level, usually near the tropopause at 10-12km.

CONTRAILS are the trails of jet aircraft whose water vapour condenses into ice crystals.

STRATUS clouds are **layer**clouds that develop with whole air masses rising gently, with limited vertical development

Stratus clouds

mulus



Stratus clouds from above







CUMULO-NIMBUS