ORIGIN OF AIR MASSES AND THEIR CLASSIFICATION

PAPER NAME: - ADVANCED CLIMATOLOGY
SUBJECT: - GEOGRAPHY
SEMESTER: - M.A. –II
PAPER CODE: - GEOG. 201

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INTRODUCTION

Air is invisible but it can very well be felt. You are aware that the air in the tube of cycle/ bike/ car reduces, it is pressed due to weight of the vehicle, which clearly manifests that air occupies certain space and it has its mass? For a clear understanding of the various types of atmospheric disturbances, the study of air masses provides an essential background. Air masses that move along as part of the large scale motion system of the general circulation are largely responsible for bringing about changes in day to day weather, particularly so in the middle latitudes. The temperate regions in the northern hemisphere may be considered to be the battle ground where air masses with contrasting physical properties very often meet. Travelling air masses transport latent heat as well as other temperature characteristics from one region to another. Air masses also carry large quantity of atmospheric moisture from over the oceans to the continents to yield precipitation over there. In this module, an attempt has been made to discuss the origin and classification air masses.

AIR MASSES

An air mass is an extensive body of air, usually many thousands to millions of square kilometres of area. It is an integral part of global planetary wind system that is located in a specific region on the surface of the earth and stays for a substantial period of time with horizontally uniform physical characteristics, such as temperature and humidity. Generally, it occupies thousands of km across encompassing subcontinental size in expense. It is usually almost horizontally uniform in temperature, pressure and humidity. The changes are observed with increasing altitude which is a general principle irrespective of area/ air mass. It is located in a specific region on uniform surface of the earth in terms of their physical characteristics. It may extend vertically up to a height of troposphere. This large volume of air stays for a substantial period of time horizontally and it attains uniform physical characteristics, such as temperature and humidity.

Air mass can also be defined as the body of air extending over a large homogenous area, which is characterized by similar physical attributes like heat and moisture of the local area. The air mass with constant contact with the underlying air of any region attains the much needed equilibrium between temperature and humidity. Such air with well-defined equilibrium, distinctive characteristics and little horizontal variation is often referred to as air mass.

The vertical distribution of temperature delineates the stability of air mass besides the degree of hotness or coldness and moisture content in the air determines the process of condensation. It forms an integral part of planetary wind system, thus associating them with one or the other wind belt. For example, both tropical and polar air mass could co-exist in the belt of westerlies. It is this air mass that transfers and distributes the heat from tropical to polar region and prevents latitudinal temperature imbalance. Inside the air mass, the horizontal gradient of temperature and moisture is weak i.e., temperature and moisture at a given height is almost same or comparable. At the margins of air masses, the horizontal gradient becomes sharp.

DEFINITION OF AIR MASS:

"An air mass may be defined as a large body of air whose physical properties, especially temperature, moisture content, and lapse rate, are more or less uniform horizontally for hundreds of kilometres". According to A.N. Strahler and A.H. Strahler (1978) "a body of air in which the upward gradients of temperature and moisture are fairly uniform over a large area is known as an air mass." An air mass may be so extensive that it may cover a large portion of a continent and it may be so thick in vertical dimension that it may vertically extend through the troposphere.

Air mass is a 3 dimensional body of air having distinctive physical properties from the surrounding and relatively homogenous in terms of specific humidity, lapse rate and density.

-G. Trewartha.

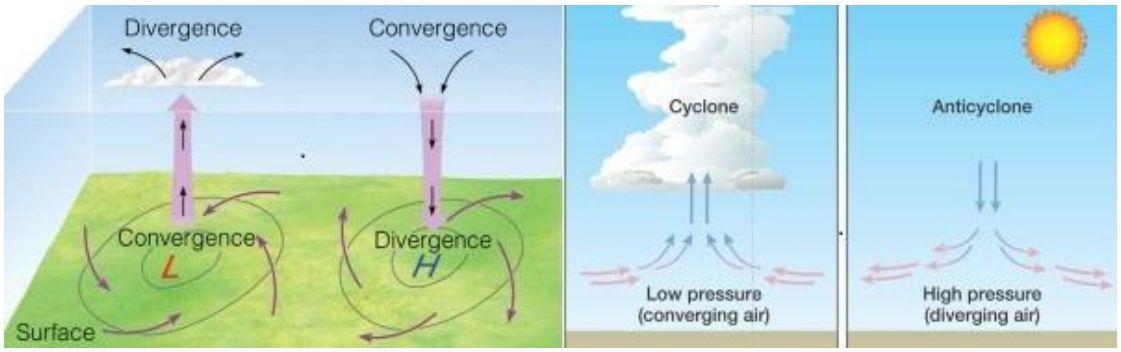
ORIGIN OF AIR MASS

The origin of air mass is dependent upon the area where it develops. Its development starts on a uniform huge area. Area where air masses are developed in a natural process is known as the source region. Air masses acquire the properties of the source region/ area in terms of temperature, pressure and moisture.

A good source region for the air mass to develop should be:

- a fairly uniform extensive area
- relatively flat and homogenous area with similar type of physical conditions

- prevailing calm conditions
- preferably high pressure conditions



Formation of Air Mass

Areas with regular high pressure zone of earth's atmospheric circulation is found in subtropical vertically air subsiding zone as well as thermally induced polar zones. In these areas, the horizontal change in pressure gradient is low while the pressure itself is high. The divergent air circulation is the ideal source region for the air mass to develop as it is a relatively stable volume of air. Mid-latitude region is dominated by cyclonic and other local disturbances. It is practically devoid of such activities.

The nature and characteristics of source region determines the characteristics of the air mass, thereby enabling the maintenance of equilibrium between heat (temperature) and moisture (humidity) with the overlying air mass. These regions are characterized by stationary or slow moving anticyclones with calm/ light winds. The air mass characteristics changes with distance from source.

DETERMINANT FACTORS OF AIR MASS

The nature of air masses is primarily determined by three factors. They are:

- Source region,
- Duration of air mass stability
- Natural changes or modification with time and space

CLASSIFICATION OF AIR MASSES

The primary classification of air masses is based on the characteristics of the source region. They could be:

- Arctic (A),
- Polar (P) or
- Tropical (T)

There are five major source regions of air masses:

- Warm tropical and subtropical oceans;
- The subtropical hot deserts;
- The relatively cold high latitude oceans;
- The very cold snow covered continents in high latitudes;
- Permanently ice covered continents in the Arctic and Antarctica.

Tropical air masses are warm and polar air masses are cold. The heat transfer processes from the arriving air mass changes the characteristics of the reached areas. Warm air mass makes the area warmer than what it was before, whereas the cold air mass turns the area cooler than the original temperature conditions already prevailing.

On the basis of the characteristics of the surface, they are:

- Continental (c)
- Maritime (m)

In addition to all mentioned above, a large variety of secondary types of air masses are categorized. For example, Equatorial or Mediterranean. Sometimes there is a letter k or w attached to the two-letter initials indicating whether the air is warmer (w) or colder (k) than the surface of origin of air mass. The colder is more stable than the warmer.

TYPES OF AIR MASSES ON THE BASIS OF SOURCE REGION

Based on Temperature Conditions

Based on temperature conditions air masses can be listed into two categories as follows:

- Polar (cold)
- Tropical (warm) and

POLAR AIR MASS (COLD)

An air mass with temperature lower than that of the underlying surface, which is generally associated with instability and high atmospheric turbulence, is termed as a cold air mass (polar or arctic). The centers of cold air masses are associated with high pressure on surface weather maps. They are heavier and denser cold air which pushes in under the warm air and rapidly forces it upward at a sharp angle, which results into steeper wedge than a warm front. They generally originate in the following regions:

- Arctic Ocean – cold and moist
- Siberia – cold and dry
- Northern Canada – cold and dry
- Southern Ocean – cold and moist

TROPICAL AIR MASS (WARM)

A mobile warm air mass is warmer than the underlying surface generally associated with stable weather conditions. The centers of very warm air masses appear as semi-permanent regions of low pressure on surface weather maps. It creates a series of wide bands of weather due to east movement of light warm air. Owing to its instability and temperature it as high humidity, hence these fronts are accompanied by cloud cover and precipitation. Based on the temperature of the surface area over which the air mass moves, same air mass can be called as cold or hot. They generally originate in the following regions:

- Tropical Deserts – warm and dry
- Tropical Oceans – warm and moist

BASED ON LATITUDINAL EXTENT

Air masses can be classified into various categories based on their source of origin and latitudinal extent. Based on the source of origin, air masses can be broadly classified into

following categories (Table 1). Air masses found in the tropical region are warm while found in polar are cold. The process of conduction or convection (for transfer of heat) helps the air mass to alter their characteristics slowly by migration/ movement or even at the same place.

Table 1: Classification and Characteristics of Air Masses

Air Mass	Symbol	Properties	Region	Temperature (º C)	Specific Humidity g/kg
Maritime Tropical	mT	Warm moist	Warm Tropical and Sub-tropical Oceans	24 º C	17.0
Continental Tropical	cT	Warm dry	The sub-tropic hot deserts	24 º C	11.0
Maritime Polar	mP	Cool Moist	Warm Tropical and Sub-tropical Oceans	4 º C	4.4
Continental Polar	cP	Cold dry	The very cold snow covered continents in high latitudes	-11 º C	1.4
Continental Arctic	cA	Very Cold and dry	Permanently ice covered continents in the Arctic and Antarctica	-46 º C	0.1

After looking on the basis of origin of air masses theoretically, many types of air masses can be listed, but in reality certain types of air masses are not possible or they are very weak and hence not considered. The abbreviations are sometimes use on weather maps to show the air mass over an area, particularly when the air masses have moved from their source regions. Air masses are practically identified at arrival and not at the origin source. Their arrival in different area creates distinct difference, and hence, they are well demarcated boundary/ zone becomes apparent (Fig 1).

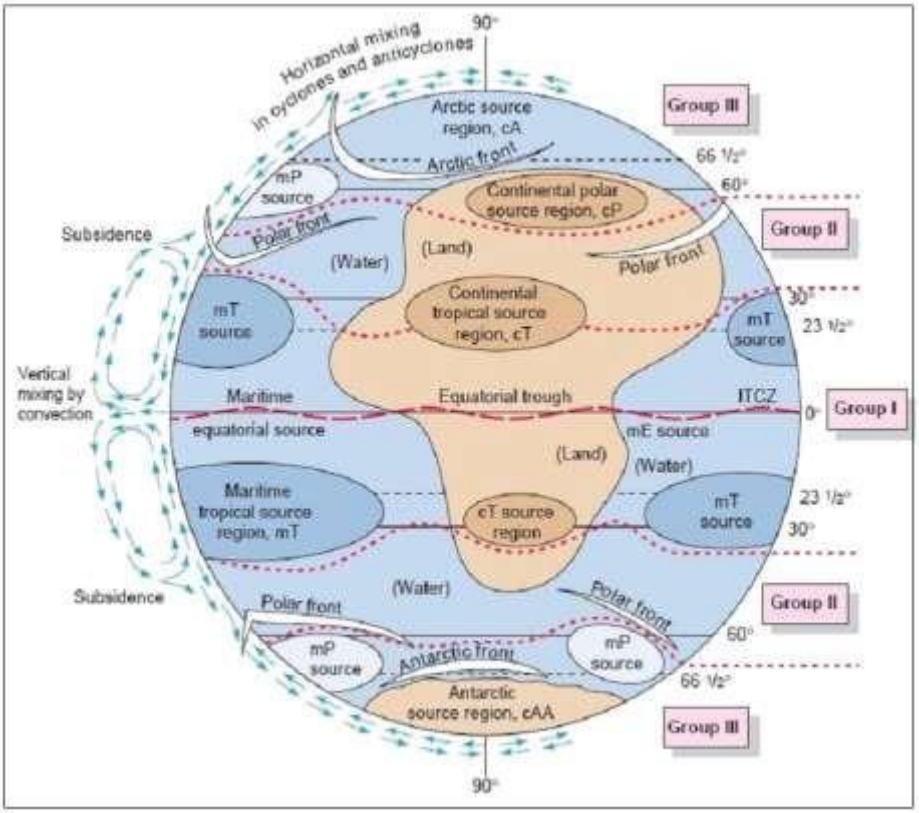


Fig. 1. A Diagrammatic Presentation of the Air Masses on the Globe

MARITIME TROPICAL

The sources of this air masses are the sub-tropical anticyclones (high pressure cells), which persist throughout the year over the oceans at about latitude 30°N and S latitudes. They originate from tropical and subtropical oceans like Atlantic and Pacific to Mexican Gulf. They are distinctly characterized during summers and winters, influencing the local climate. The air is warm, unstable and humid owing to warm water from seas beneath them. The air absorbs abundant moisture from the lower layers during summer as the ability to absorb moisture is more in high temperature. After that the stable air starts moving upwards, from subtropical to higher latitudes and slowly starts cooling down due to contact with the cold sea and land ass over which they pass. It results in the reduction of normal lapse rate (inverse), which increases stability and minimizes the turbulence. This cooling process from the lower layer gradually increases the relative humidity and the dew point is reached. The combination of these two factors produces fog and light drizzle to steady rain with the formation of stratus clouds. Here, winters are mild with overcast conditions accompanied by fog. This air mass invades hot continental part and moves over the warmer seas in summer, which shows

instable characteristics with heavy rain. Majority of the eastern coastal parts of mid latitude receives maximum rainfall from this air mass. On the other hand, Summer witnesses high temperature and humidity, which is accompanied by cumulous cloud and convectional rain.

CONTINENTAL TROPICAL

These are hot, stable and dry winds that originate from tropical and subtropical desert area of North Africa (Sahara), Asia and Australia. These tropical continental dry winds originate from North Africa in winters (locally known as Harmattan) and are found in western drier margins of North America (USA) in summers. These air masses generally do not extend beyond their source. These types of air mass also originate from drier parts of Australia. This air remains hot and unstable during summers and dry throughout the year with minimum humidity. High temperature and low humidity leads to high condensation level with no rainfall, despite being in instable zone. On the other hand, in winter the air remains warm and dry but is stably stratified[1] as it is found in anti-cyclonic zones with descending air. This stable wind hardly moves and thus, it is localized. But when it moves towards cooler surfaces, its stability increases where it meets cold air masses. Such front occurs in the Mediterranean region. Overall, this air mass is dry throughout the year with scanty rainfall unlike tropical maritime.

CONTINENTAL POLAR

As the name suggests, these air masses originate from polar areas like Antarctica, Arctic basin, Eurasia and northern North America. These air masses are dry, stable and very cold. Here, the wind circulation is gentle and divergent. The winds are very dense and cold mainly due to distance from the warmer water bodies (oceans) and continued (prolonged) terrestrial radiation. These winds are warm, less stable in summers with less or no prevalence of anti-cyclonic winds. Winters are frigid, clear and stable with meagre cloudiness leading to precipitation in the form of snow or ice.

MARITIME POLAR

Maritime polar air masses originate from the oceans located across 40° and 60° latitudes. Such continental polar masses move over warmer water bodies like oceans, gets heated up and absorbs moisture (humid) owing to increased temperature is referred to as maritime polar air mass. This region is characterized by cool, moist and unstable air. These regions are the regions which cannot lie stagnate for long. Summers are stable, clear and fair in this zone while winters are characterized by high humidity, mild temperatures, overcast skies conditions and occasional fog and precipitation. Various fronts and air movement across the globe can be seen from (Fig. 1)

CONTINENTAL ARCTIC

These air masses form over large areas of snow and ice typically near the poles in both hemispheres. Arctic air masses tend to form during winter December to March in the Nothern Hemisphere and June to September in the Southern Hemisphere, when the Poles are quite cold and without much insolation.

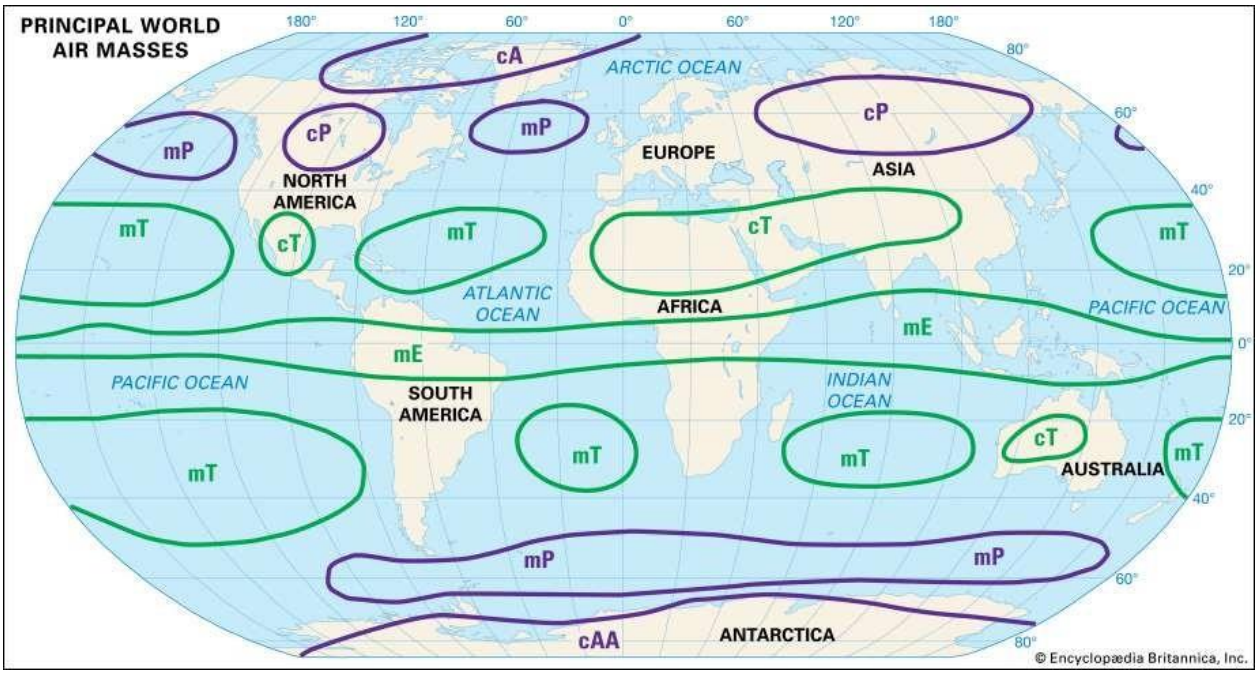


Fig. 2. Principal Air Masses on the Globe

CONVERGENCE OF AIR MASSES AND FRONTS

Different air masses originate and move out from different sources, but they all eventually meet in a region of convergence zone of low pressure (Fig.3). At the interface zone, both cold and warm air masses meet, and it results only marginal mixing. The air masses primarily retain their own characteristics in the upper layers, it is unaffected and un-disturbed. The instability and turbulence occur in the lower atmosphere, near to the earth surface. This phenomena of meeting and mixing of different air masses by convergence results in occupying the space of warm air mass by colder and denser one. The warmer and lighter air mass shifts over the colder and heavier one. This ascent and convergence of fronts results in condensation and precipitation. The intensity of the disturbances that accompanies this process of convergence is proportional to the humidity and temperature. Generally heavy storms are common phenomenon when polar air mass converges with subtropical air mass.

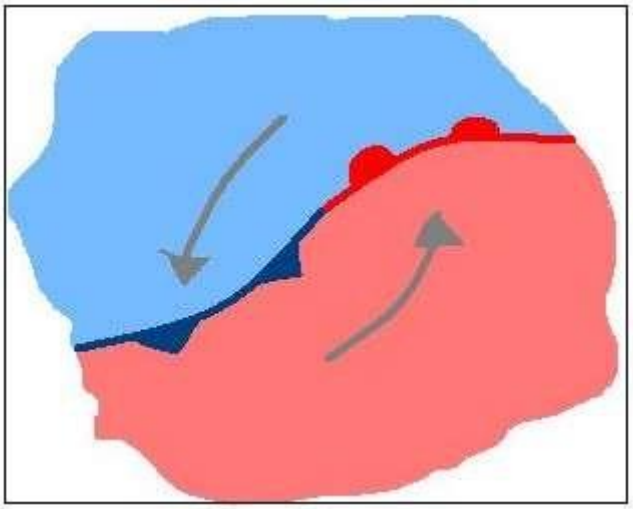


Fig. 3. Convergence of air masses

STATIONARY FRONTS

When a frontal system stops moving forward, a stationary front occurs (Fig.4). Stationary fronts may result from the stalling of either a cold or warm front, and may remain stationary for several days. When a stationary front starts to move again, it may be either a warm front or a cold one. The discontinuity of temperatures often weakens and the front simply dissipates. In a stationary front the weather conditions are fair and stable.

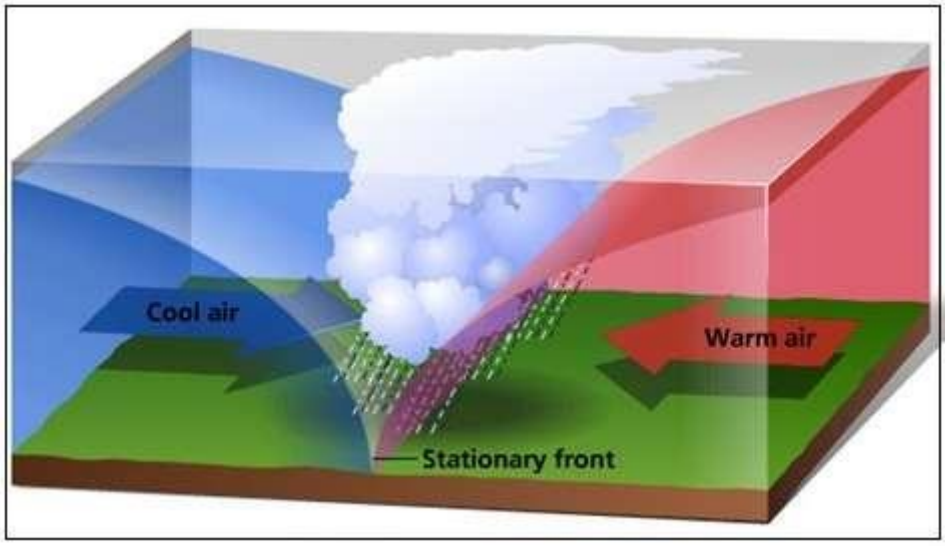


Fig. 4. Formation of stationary front

OCCLUDED FRONTS

An occluded front develops during the latter state of dissipation of a depression when the combined front of the air mass is detached from the ground. There are two types of occlusion cold front type and warm front type (Fig.5). Occlusion takes place when a mass of warm air is pushed upward and removed from the ground by dense mass of cold air. The warm sector diminishes and the cold air mass completely undertakes the warm sectors on ground. Thus a long a backward swinging and occluded front is formed which could be a warm type or cold type occlusion. Weather along an occluded front is complex a mixture of cold front type and warm front type weather.

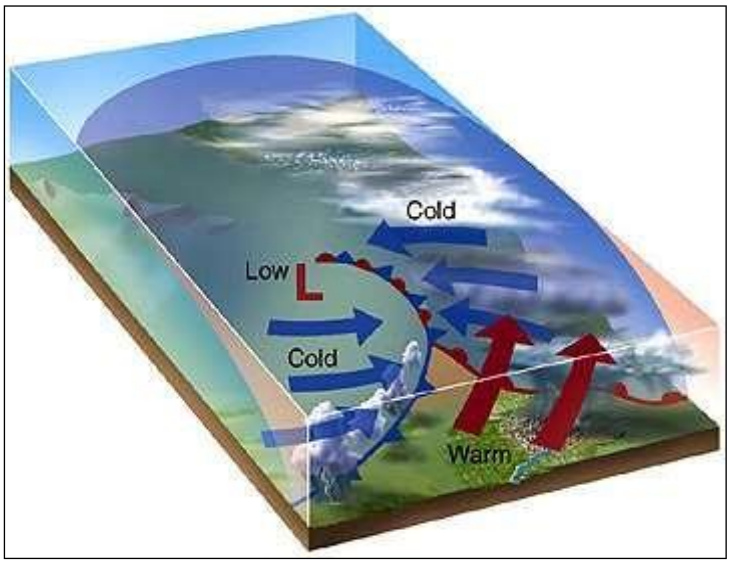


Fig. 5. Occluded front

AIR MASSES MODIFICATION

The properties of an air mass influence the areas of its occurrence.–Air masses normally migrate from their source regions to other nearby/ surrounding regions. The moving air masses undergo two types of air modifications. They are: (a) thermodynamic modifications, and (b) mechanical modifications.

THERMODYNAMIC MODIFICATION

Thermodynamic modification is caused by the transfer of heat from the moving air mass to the moved places and simultaneously gets modified by the moved places by acquiring the characteristics of that area. Thermodynamic processes include such effects as heating from below decreases the vertical stability. Other includes evaporation of water into the air mass from below or into the intermediate layers by precipitation from the overlaying moist air layers. The extent to which an air mass is modified depends upon

- the initial temperature,
- moisture conditions,
- the path taken by air masses
- the nature of underlying area and
- time taken or duration of travel;

An air mass moving over a surface that is warmer than the ground temperature is bound to be heated from the below with consequent steepened lapse rate and stability. These changes create the chances of condensation and precipitation. An air mass moving over a colder surface is cooled from below. This condition favors the formation of a surface inversion which increases the stability of the air mass. Under such conditions, formation of the clouds and precipitation is not possible. As the polar air masses move out of their source regions they tend to became more and more stable. The Tropical air masses on the other hand undergo the second type of modification and develop n increased stability.

Thermodynamics changes are brought about by increased evaporation. The moisture may be supplied either from the surface over which and air is moving, or by precipitation from an overlay layer of the air mass itself.

MECHANICAL MODIFICATION

An air mass may undergo changes due to any of the following reason/s.

- Turbulent mixing caused by eddies or convection.
- Large-scale dynamic effects on in lapse rate; divergence; convergence
- Subsidence or sinking: in subsidence and latent spreading: movement down from above colder air masses; descent from high elevations to low lands.

- Lifting: over colder air masses; to compensate for horizontal convergence; over elevations of the land.
- Advection of new properties aloft due to shearing action of the wind.

Mechanically induced turbulence resulting from frictional effects at the surface may cause through mixing, often to a considerable height. Heat and moisture are transferred from the surface to various layers to atmosphere, thus modifying air masses considerably. Large scale divergence or convergences near or above the surface may cause upward or downward movement of extensive portions of the atmosphere and affect atmospheric stability. A descending air mass, as one descending on the leeward side of a physical barrier becomes more stable by subsidence. Lifting of an air mass in the case of an orographic or a frontal uplift renders it more unstable.

One can understand a lot about weather conditions from air masses just by looking at their names and origins. Maritime air masses possess good amount of moisture. The air blowing over the warm ocean regions picks up moisture from the humid/ moisture laden wind as it travels along. The air mass/ wind carries atmospheric moistures from oceans to continents and cause precipitation over landmasses. In maritime arctic and Polar Regions, this moist air is cool and the maritime tropical air mass produces the warm and humid conditions. In contrast, continental air masses produce dry weather. This is because the continents just can't compete with the oceans when it comes to moisture. The continental arctic and polar air masses produce dry and cold weather in the winter and pleasant weather conditions in the summer.

Air masses transport latent heat thus, removing the latitudinal heat balance. Most of the migratory atmospheric disturbances such as cyclones and storms originate at the contact zone between different air masses and the weather associated with these disturbances is determined by characteristics of the air masses involved.

CONCLUSIONS

An air mass is a regional parcel of air developed over an area where it has remained for a longer period and gained a particular temperature and moisture conditions. There are four basic types of air masses. They are - tropical maritime, tropical continental, polar maritime and polar continental. Additional extremes are polar maritime and Antarctic continental. Continental air masses are relatively dry and maritime air masses are relatively humid and are

classified on the basis of moisture availability. They generally originate in the following regions: Arctic Ocean – cold and moist, Siberia – cold and dry, Northern Canada – cold and dry, Southern Ocean – cold and moist. Polar maritime air is more common in both hemispheres with source region in high latitude oceans. Polar continental air occurs in the northern hemisphere while Antarctic continental occurs in southern hemisphere. Tropical maritime air mass is common in both the hemispheres, but tropical continental air is less common due to lack of large landmass in the subtropics. India becomes a source region for tropical continental air in winter due to cold prevailing conditions. In the summer, the high pressure over Siberia combined with Himalayan mountain chain restricts the movement of continental tropical air mass northwards. Air masses are modified by the earth surface. If the surface is colder than the air mass the stability of the air will be increased and if surface is warmer, it will be decreased and cloud formation and precipitation may result.