Date: 04.11.2020

Geography (Hons)-Paper-CT5-3rd Semester

Air mass: Typology, origin, characteristics and modification.

Questions

1. Discuss the salient features of air mass source regions.
2. Classify air masses with their salient features.
3. Mention the bases of classifying the air masses.
4. What is thermodynamic modification?

Air Mass:

An **air mass** is an immense body of air, usually 1600 kilometres or more across and perhaps several kilometres thick, which is characterised by homogenous physical properties (in particular temperature and moisture content) at any given altitude. Since it may extend through 20 degrees or more latitude and cover hundreds of thousands to millions of square kilometres, the horizontal homogeneity of an air mass is never complete. Small differences in physical properties (especially temperature and humidity) from one point to another at the same level are bound to occur. But the internal differences of an air mass are small in comparison with the much more rapid rates of change that are experienced across the boundaries between different air masses. Since an air mass traverses an area in several days, the region occupied by it will generally have the same weather conditions except some day to day variations here and there. But the weather conditions in an adjacent air mass are altogether different. Along the margins of the air masses the weather changes are rather very sharp.

Genesis of Air Mass:

When air remains in contact with a large and uniform surface for a couple of days, its temperature and moisture attain equilibrium with the surface. If the underlying surface is warm, the overlying air will be warmed and the entire mass of air lying above will be heated gradually by conduction. If the surface is cold, the air above it will naturally be cooled and the heat will be removed from the lower part of the air. Similarly, the moist surface will impart its moisture to the air above it, whereas the overlying air will lose moisture to the underlying dry surface. The time taken to reach a state of equilibrium may vary from two or three days to a week or two. It shows that once equilibrium is reached, it will change only slowly with time. Such an extensive portion of the atmosphere that has acquired some sort of equilibrium with the surface by remaining into its contact over a large area is designated as an air mass. Such a large uniform surface is called an **air mass source region.**

Air-masses retain their identity even after they have moved far from their source region. But the original physical properties are conserved only in the upper parts of such air masses. This is so because the process of conduction is rather slow, convection is almost absent in stagnant and stable air and the process of radiation is not effective in the free air except at cloud surfaces.

The following two characteristics of an air mass control the weather associated with it:

i. The vertical distribution of temperature in an air mass and
ii. The moisture content of the air.

The vertical distribution of temperature is indicative of the stability of an air mass besides its warmness or coldness. The vertical distribution is closely related to the ascent or descent of air currents within the body of the air mass itself. The presence or absence of condensation forms is determined by the moisture content of the air.

According to **Trewartha**, air masses are an important and inseparable part of the planetary wind system. Therefore every air mass is related with one or the other permanent wind belt. Tropical maritime and tropical continental air masses are found in the trade wind belts. However, sometimes tropical as well as polar air masses co-exist in the belt of westerlies. These air masses may be either continental or maritime. In fact, when the air masses move out of their source regions, they may be taken to be the streams of tropical or polar air on a gigantic scale. Actually it is through these extensive air streams that heat is transferred from the tropical to Polar Regions. Thus, the air masses play an important role in removing latitudinal imbalances in heat.

An air mass with temperature lower than that of the underlying surface is designated as a **cold air mass**. On the other hand, a mobile air mass which is warmer than the underlying surface is labelled as **a warm air mass**. The same air mass may be called *warm or cold* with reference to the *temperature of the surface over which it moves*. For example, if a warm air mass moves from a cold land surface to warm oceanic surface, it will be known as a cold air mass. Similarly, what is a cold air mass during the day becomes a warm air mass during the night because of the rapid cooling of land by nocturnal radiation. But the most important feature of air masses is that they are independent in respect of their temperature and humidity characteristics. Air masses with different densities, even when they came into contact with each other, do not merge into each other but retain their identity.

The cold air masses are marked by instability and atmospheric turbulence. Because of the heating of the air lying close to the surface, convectional currents are set up which make the air mass unstable. On the contrary, the warm air masses are cooled from below because of which vertical movements in the atmosphere are non-existent. Therefore, such warm air masses have marked stability in them.

Source regions:

Areas where air masses form are known as source regions. The nature of the source region largely determines the temperature and humidity characteristics of an air mass.

There are two essential features which make an ideal source region.

i. It must be an extensive and broadly uniform surface of the earth. If a region has irregular topography or it has a surface consisting of both water and land, then it is not considered satisfactory.
ii. The area should have a comparatively gentle and divergent air flow so that air will stay over the region for a considerable long period of time to reach some measure of equilibrium with the surface. Therefore the regions with high barometric pressure and low barometric gradients are the ideal source regions. In other words, the source regions are characterised by stationary or slow moving anticyclones with their extensive areas of calms or light winds.

Cyclonic areas being characterised by converging surface winds do not favour the formation of air masses. Conditions which produce air masses are well developed over the tropical seas and hot deserts during much of the year and over the Arctic region, particularly in winter. These areas may be considered as the **Primary Source Regions** of air masses.

There are other extensive regions with uniform surface over which air flow is generally not stagnant. If the air that passes over such a region can be transformed rapidly, it may acquire unique characteristics. Such regions are referred to as **Secondary Source Regions**. Primary source regions may be either warm or cool because the air may be stagnant for longer periods to establish equilibrium. But the secondary source regions should either be relatively warmer than the overlying air, or otherwise extensive.

It is noteworthy that no major source regions are found in the middle latitudes. They are generally confined to tropical or polar locations. Since regions in the middle latitudes are dominated by cyclones and other types of storms, they do not possess the homogenous conditions so essential for a source region.

Examples of primary source regions are the following:

i. The tropical Atlantic ocean around Bermuda
ii. The tropical Pacific ocean around Hawaii
iii. The Sahara Desert Region and
iv. The interior of Siberia.

Examples of Secondary source regions are the following:

i. The North Pacific Ocean between Siberia and Canada
ii. The North Atlantic Ocean between Canada and Northern Europe and
iii. The arid South West of the United States.

Typology of Air Mass:

All the physical properties of air masses which determine the weather characteristics produced by them are acquired from their source regions. When the air masses move out from their source regions, the temperature, humidity and the nature of the underlying surface bring about certain changes in them. Therefore, a satisfactory classification of air masses must encompass these transitions. No classification scheme should be based on geographical location of various air mass source regions alone.

Air masses are classified on the basis of

i. The location of their source regions and
ii. The nature of the surface over which they move towards other regions.

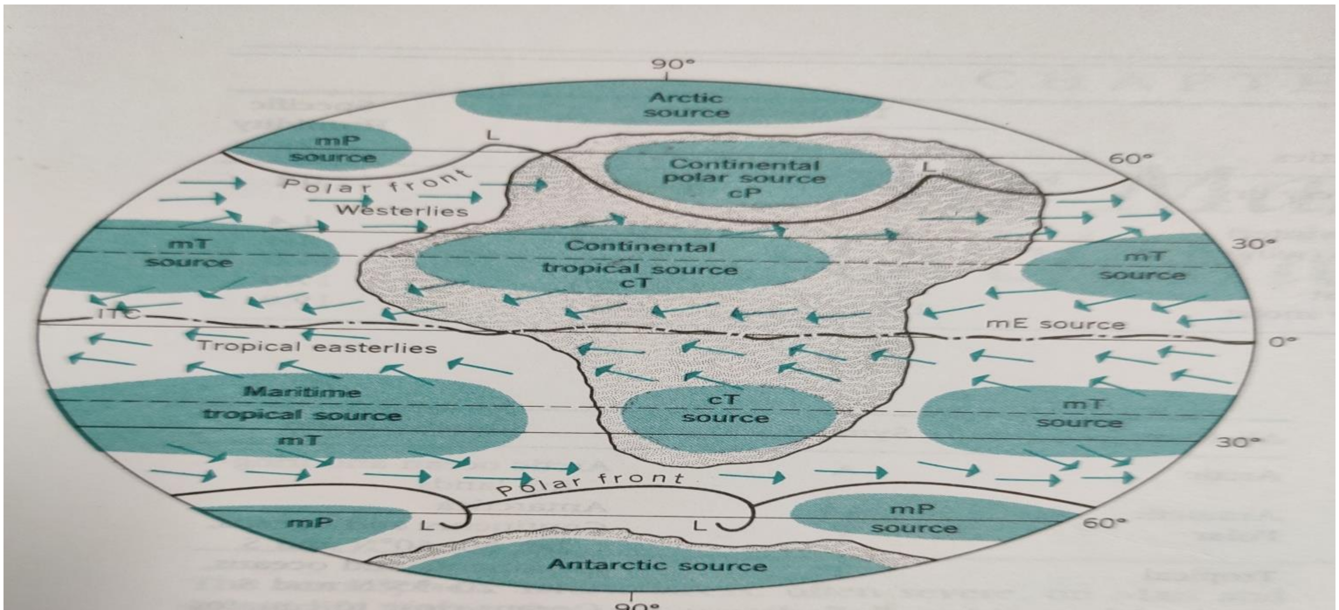

FIGURE 8.1 A schematic global diagram showing the source regions of air masses in relation to the polar front and the intertropical convergence zone.

Petterssen has classified air masses into the following five major categories on the basis of their <u>source regions:</u>

i. Tropical air masses
ii. Polar air masses
iii. Equatorial air masses
iv. Arctic air masses and
v. Antarctic air masses

But according to **Byers**, there are only three major categories of air masses—

i. Arctic
ii. Polar and

iii. Tropical

Trewartha, on the basis of the geographical location of air masses, classifies them into the following two broad categories:

i. Polar air mass, for which a capital **P** is used
ii. Tropical air mass, for which a capital **T** is used

He is of the opinion that Arctic, Antarctic and Equatorial air masses do not have their individual identity of their own. They are considered to be the modified forms of polar and tropical air masses.

He further subdivides the polar as well as tropical air masses into two types on the basis of the nature of the surface of their source regions, i.e., land or water:

i. Continental air mass indicated by a small letter **c**
ii. Maritime air mass indicated by a small letter **m**

The continental air masses originate over the continents, and the maritime air masses form over the oceans. Maritime air masses have originally large quantity of moisture which they have picked up from the oceans over which they were formed. They have, therefore, a natural tendency for condensation in them. On the contrary, the continental air masses are originally dry. When they move out to oceans, they acquire a large amount of moisture by the process of evaporation from the sea surface. In this way the continental air masses develop the characteristics of maritime air masses gradually. Similarly, the maritime air masses while passing over the continents lose their moisture and undergo modification rather slowly.

Hence on the basis of the —

- source regions
- as well as the nature of their surface

the following four principal types of air masses may be considered:

i. Continental Polar air masses (**cP**)
ii. Maritime Polar air masses (**mP**)
iii. Continental Tropical air masses (**cT**)
iv. Maritime Tropical air masses (**mT**)

Besides the above classification,—

- when various thermodynamic and
- mechanical modifications of the air masses are taken into consideration,

a more elaborate classification consisting of the 16 types is obtained:

K=Heated from below

W=Cooled from below

s=stable aloft

u=unstable aloft

Air masses according to source regions:

The principal source regions of the earth may be classified according to the nature of surface (land and water) and the latitude of the region. Thus, the source regions are classified as under:

Surface	**Latitude**
Continental	Arctic
Maritime	Polar
	Tropical
	Equatorial

The arctic source regions are located in the high latitudes where the surface is permanently covered with snow and ice. Thus they are the coldest regions on earth. The polar source regions do not mean the regions around the geographic poles. They are situated between the Arctic source regions and the sub-tropical highs. Notable, that the Arctic source regions are colder than the polar source regions. The tropical source regions occupy the subtropical high pressure belt. The equatorial source regions are located around the equator between the trade winds of the northern and southern hemispheres.

The following discussions relates to the major air masses that form during the winter and summer months in different regions of the world:

i. **Continental Polar (cP) air masses during winter:**

These air masses have their source regions in Central Canada and Siberia. They are extremely cold, dry and stable. Since the surface is completely frozen and is snow or ice covered, these air masses are the coldest wintertime air masses. They produce intense cold waves when they move out to some other regions. Because of extreme dryness of the air, there are no clouds in these air masses. However, after these air masses move out of their source regions, they are modified while they pass over a warm surface. When cP air mass becomes cPK after modification, cumulus or stratocumulus is not uncommon.

ii. Continental Polar (cP) air masses during summer:

These air masses have their source regions in the Central parts of high latitude continents. Central Canada offers a typical example of such source region. Because of surface heating, snow cover disappears. Summertime cP air masses in their source regions are cool and dry, but not necessarily stable. Actually these are the modified forms of the wintertime cP air masses which have been heated in the lower layers. Their lapse rates are comparatively less steep. When cPK air mass moves out to oceanic surface, it is modified into cPW air mass with haze, fog, and low stratus clouds.

iii. Maritime Polar (mP) air masses during winter:

These air masses are cool and moist and form over the open oceans in the higher latitudes. They are originally cP air masses which have undergone extensive modification over the open oceans. These air masses contain few clouds in their source regions. But when they are dragged into cyclones or are forced to ascend mountain barriers, extensive precipitation is produced by them. Their lower layers are moist and unstable, but they are dry and cold in their upper parts. The convective instability in the lower layers of these air masses produces showery, squally weather.

iv. Maritime Polar (mP) air masses during summer:

These air masses originate in the source region of mP air masses. They are cool and moist in the lower parts, but dry aloft. A temperature inversion is produced sometimes with moisture

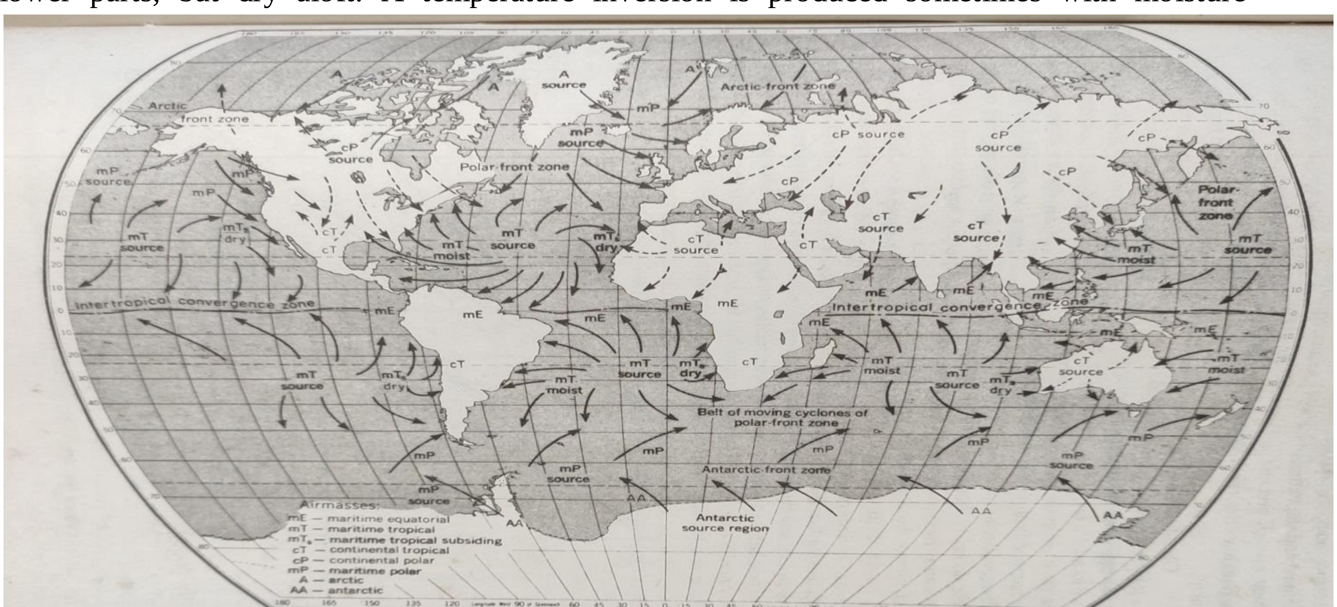

Figure 5.3 Principal air masses and source regions of the world. (Data after Strahler, courtesy John Wiley & Sons, Inc.)

discontinuity. They are stable up to moisture discontinuity. The general temperature is slightly higher than that in the mP air masses.

v. Tropical Maritime (mT) air masses during winter:

They have their source regions over the warm oceans in both the hemispheres. They are warm, moist and unstable. They release abundant precipitation whenever they occur. The lapse rates in the lower layers often approach the dry adiabatic rate and the lapse rates are steep up to tropopause. Moisture is well distributed to high levels. When these air masses are lifted over fronts or high mountains, they produce heavy precipitation.

vi. Tropical Maritime (mT) air masses during summer:

The source regions of these air masses are located in the belt of the great semi permanent highs of the tropical oceans including the Caribbean Sea. The mT air masses are very warm and moist and highly unstable. These air masses have convective instability.

vii. Continental tropical (cT) air masses:

These air masses have their source regions in the sub-tropical high pressure land areas. They have high temperatures and low moisture content. The tropical continental air does not spread extensively beyond its source regions. In the United States these air masses are important only in the summer season. They are dry both in winter and summer. In summer they are very hot. Subsidence and stability are found in the upper parts of these air masses in their source regions. When cT air is found aloft over warm, moist air at the surface, the atmosphere becomes convectively unstable and violent thunderstorms or tornadoes are produced.

Air Mass modification:

Air masses normally migrate from their source regions to other regions which have different surface properties. As the air masses move out from their source regions, they not only modify the weather of the areas they occupy, but they are also modified to a certain extent by the surface over which they are moving.

As air masses move away from their source regions, they retain all the physical properties. These initial conditions of an air mass, as they are referred to, include

i. its vertical temperature distribution,
ii. moisture content and its distribution,
iii. mean temperature,
iv. vorticity and
v. Wind velocity, etc.

Variation in these physical characteristics is found in the vertical distribution. Air masses have the unique property of being homogenous in their horizontal extent. But the climatic characteristics of the areas traversed by air masses do modify them. Warming or cooling from below, changes in radiation rates, addition of moisture or loss of it, subsidence or uplift are some of the factors which bring about changes in air mass. Thus, it is clear that the weather of a region dominated by a particular air mass depends to a large extent on the changes that have brought about in the air mass itself. There are two principal types of air mass modifications:

i. Thermodynamic modifications and
ii. Mechanical modifications.

The above two modifications may occur either separately or in combination

i. Thermodynamic modifications:

Thermodynamic processes include—

- Such effects as heating from below which decreases the vertical stability

Other thermodynamic effects include—

- Evaporation of water into the air mass from below
- Into intermediate layers by precipitation from overlying moist air layers.

According to **Trewartha** the extent to which an air mass is modified depends upon —

i. initial characteristics of the air mass (its temperature and moisture content)
ii. nature of the underlying surface
iii. path followed by the air mass and
iv. the time taken to reach the point of observation

An air mass moving over a surface that is warmer than the ground temperature is bound to be heated from below with consequent steepened lapse rate and instability. These changes create the changes of condensation and precipitation. On the other hand, an air mass moving over a colder surface is cooled from below. This condition favours the formation of a surface inversion which increases the stability of the air mass. Under such conditions, formation of clouds and precipitation is impossibility. From the above it is obvious that as the polar air masses move out of their source regions they tend to become more and more unstable. The tropical air masses, on the other hand, undergo the second type of modification and develop as an increased stability.

Capital letters **W** and **K** standing for **'warm'** and **'cold'** respectively represent such modifications of the initial properties of an air mass. W is indicative of a warmer air mass being cooled from its basal layers and holding no possibility of cloud formation or precipitation. K represents an air mass that is colder than the underlying surface and that is being heated from below. Such a change makes the air mass unstable. It should be noted that these letters simply indicate the relative temperature of an air mass with respect to the underlying surface.

Thermodynamic changes are brought about by **increased evaporation**. The moisture may be supplied either from the surface over which an air mass is moving or by precipitation from an overlying layer of the air mass itself. On the other hand, condensation or precipitation by extracting moisture from the air mass may also cause changes. Similarly, addition or loss of latent heat accompanying the process of condensation and precipitation may also bring about thermodynamic changes in an air mass.

ii. Mechanical (dynamic) modifications:

According to **Byers**, an air mass may undergo changes because of any one or more than one of the following mechanism:

i. Turbulence mixing caused by eddies or convection.
ii. Large-scale dynamic effects on lapse rate; divergence and convergence.
iii. Sinking: in subsidence and lateral spreading; movement down from above colder air masses; descent from high elevations to low lands.
iv. Lifting: over colder air masses; to compensate for horizontal convergence; over elevations of the land.
v. Advection of new properties aloft due to shearing action of 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 of the atmosphere, thus modifying the air mass considerably. Large scale divergence or convergence near or above the surface may cause upward or downward movement of extensive portions of the atmosphere and affect atmospheric stability. Subsidence produces stable stratification in the atmosphere, whereas convergence makes an air mass more unstable. A descending air mass, as one descending on the leeward side of a physical barrier, becomes more stable by subsidence. Contrarily, lifting of an air mass as in the case of an orographic uplift or a frontal uplift renders it more unstable. In other words, ascending air is accompanied by a steepening of the lapse rate which makes an air mass unstable. Besides the above mentioned vertical motion, advection of warm or cold aloft may affect the stability of an air mass.

Taking into account these upper level factors **Petterssen** has suggested the following classification of air masses:

1. **s** air masses which have upper-level stability and
2. **u** air masses which have upper-level instability

s air masses are always found in those regions of the earth which are dominated by anticyclones. In these regions there is advection of warm air in the upper atmosphere. u air masses, on the contrary, are normally found in cyclonic regions where there is advection of cold air aloft.

Latitudinal Zone	Latitudinal Extension
Equatorial Zone	10° N to 10°S
Tropical Zone	10° to 25 ° N & S
Sub-tropical Zone	25° to 35°N & S
Mid latitude Zone	35 °to 55°N & S
Sub arctic and Sub Antarctic Zones	55 °to 60°N & S
Arctic and Antarctic Zones	60° to $66\frac{1}{2}$ °N & S
Polar Zones	$66\frac{1}{2}$ ° /75° to 90° N & S`

Strahler & Strahler, Modern Physical Geography (3rd Edition), John Wiley & Sons, Toronto, Page-58-59.