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ATMOSPHERIC BOUNDARY LAYER

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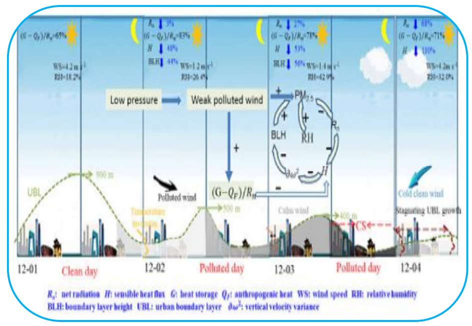
ABSTRACT:

THE ATMOSPHERE: *The atmosphere is a layer of gases covering the surface of the earth. The earth and its atmosphere receive heat in the form of radiation from the Sun, and are cooled by radiation back to space. The resulting variations in the temperature of the atmosphere give rise to winds and weather patterns. The evolution of the atmosphere is dominated by stratification (**Figure -1** shows variation in temperature with height) and rotation of the earth**. Figure 2** illustrates a typical day time evolution of the atmospheric boundary layer in high pressure conditions over land. The solar heating causes thermal plumes to rise, transporting moisture, heat and aerosols. The plumes rise and expand adiabatically until a thermodynamic equilibrium is reached at the top of the atmospheric boundary layer. The moisture transferred by the thermal plumes forms convective clouds. Drier air from the free replacing rising air parcels. The part of the troposphere between the highest thermal plume tops and deepest parts of the sinking free air is called the entrainment zone.*



KEYWORDS: *Atmospheric Boundary Layer, Indian Monsoon,*

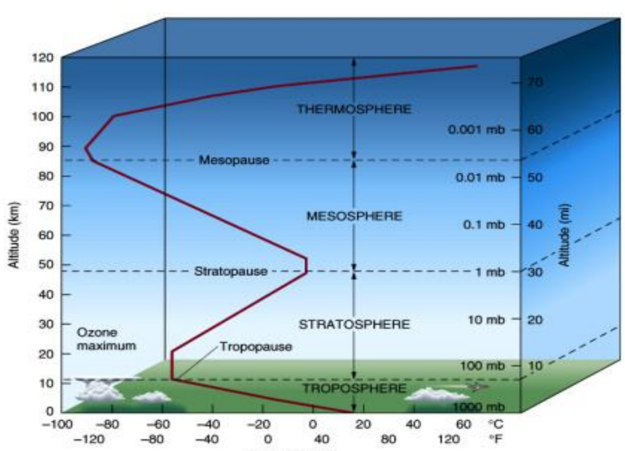


Figure -1 - shows Layers of the earth -variation in temperature with height

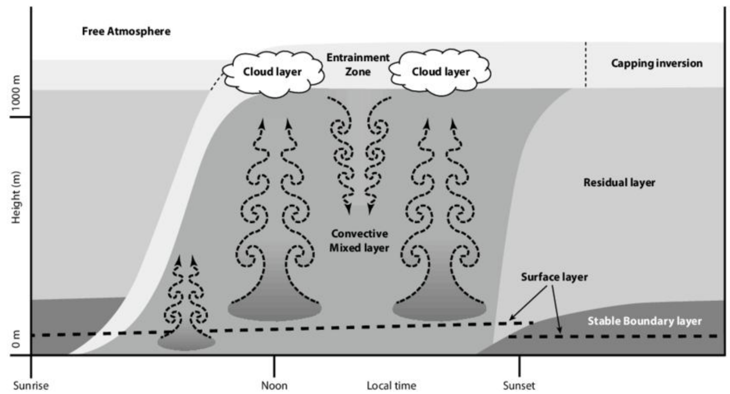


Figure 2. A typical day time evolution of the atmospheric boundary layer

THE BOUNDARY LAYER - ITS BEHAVIOUR

In physics and fluid mechanics, the boundary layer is that layer of fluid in the immediate vicinity of a bounding surface. In the atmosphere it is the air layer near the ground affected by diurnal heat, moisture or momentum transfer to or from the surface. On an aircraft wing it is the part of the flow close to the wing. The boundary layer effect occurs at the field region in which all changes occur in the flow pattern. The boundary layer distorts surrounding non viscous flow which is a phenomenon of viscous force and this effect is related to the Leiden frost effect and the Reynolds number.

The lowest layer of the atmosphere is called the troposphere. Stull(1) defines the atmospheric boundary layer as "the part of the troposphere that is directly influenced by the presence of the earths surface, and responds to surface forcings with a time scale of about an hour or less." In this layer physical quantity such as flow velocity, temperature, moisture etc display rapid fluctuations and vertical mixing is strong. Above the atmospheric boundary layer is the free atmosphere where the wind is approximately geostrophic while within the boundary layer the wind is affected by surface drag and turns across the isobars.

The atmospheric boundary layer is the lowest layer of the troposphere where the wind is influenced by friction. The thickness of the boundary layer is not a constant. At night and in the cool season it tends to be lower in thickness while during the day and in the warm season it tends to have a higher thickness. The two reasons for this are the wind speed and thickness of the air as a function of temperature. Strong wind speeds allow for more convective mixing. This convective mixing will cause the layer to expand. At night, the boundary layer contracts due to a reduction of rising thermals from the surface. Cold air is denser than warm air; therefore the atmospheric boundary layer will tend to be shallower in the cool season.

CHARACTERISTICS OF THE ATMOSPHERIC BOUNDARY LAYER

Firstly, wind is turbulent and gusty within the boundary layer. Surface friction from vegetation and topography causes turbulent eddies and chaotic wind patterns to develop. Above the boundary layer, the wind speed is much more uniform and stronger due to a marked decrease in friction and in the mid-latitudes the wind is termed geostrophic. A geostrophic wind is the balance of the pressure gradient and Coriolis force. In this layer, the frictional force is added to the pressure gradient force and Coriolis. The balance of these three forces is termed the gradient wind. Friction causes air to spiral into low pressure since friction reduces the magnitude of the Coriolis force. From the bottom to the top of the boundary layer, it is common to notice the winds veering or backing. This is often due to the decrease in friction as an important force with height.

Secondly, the temperature of the atmospheric boundary layer is dominated more by advection and thermal energy budgets than levels above the boundary layer. The earth gains most of its energy and losses most of its energy from the layer surface. It is warmed through solar heating and cooled through long wave radiation emissions. The most dramatic temperature changes occur within the boundary. It can warm up significantly during the day and cool at night while the rest of the atmosphere stays at a fairly uniform temperature and it is the major supplier of heat and moisture to thunderstorms. Temperature advections and moisture advections are important to monitor when forecasting. An increase of moisture and heat to this layer will cause the atmosphere to become more unstable.

The depth of the atmospheric boundary layer can be determined most easily by looking at a thermodynamic sounding. The top of this layer is often marked with a temperature inversion, a change in mass air, a hydro lapse, and change in wind speed and/or a change in wind direction. Inversions trap air within the boundary layer and do not allow convection to occur into the middle and upper atmosphere. The boundary layer is most definable in situations where differential advection is occurring or when a shallow front is at the surface. At the top of a front, there is an abrupt change in air mass. In some cases the transition between this layer and free atmosphere is not well defined. However, a general height of the boundary layer can be determined by looking for subtle changes in dew point and wind speed/direction. The extent of the height of the boundary layer ranges anywhere from 100 to 3000m from the surface and what exists above this height is known as the free atmosphere.

The behaviour of the boundary layer is dominated by two physical processes of due to radiative cooling and heating of the surface. Strong solar heating leads to turbulent convection and mixing in the boundary layer, whereas strong cooling at night tends to stabilize the boundary layer. The wind flowing over the surface becomes turbulent in the boundary layer and it becomes gusty and which has an important impact on the transport of heat, moisture and chemicals from the surface to higher levels of the atmosphere.

The atmosphere boundary layer is an inherently complex and heterogeneous system, which is under permanent transition, enforced by a variety of internal and external factors. An understanding of the atmospheric boundary layer, its structure and dynamics is essential for weather prediction and environmental studies. The structure of the atmospheric boundary layer shows many similarities to the two dimensional turbulent layer generated in a wind tunnel, in that both have a distinctive inner region and outer region. In the outer region, the flow shows little dependency on the nature of the surface and, in the atmosphere, the coriolis force due to the earth's rotation. This region is sometimes referred to as the Ekman layer, since Ekman (1905) first dealt with the effects of rotation on boundary-layer flow in the ocean. The inner layer termed as the wall or surface layer is mainly dependent on the surface characteristics and is little affected by rotation. The transition between the inner and outer layers is not abrupt, but is characterized by an overlap region. The influence of the surface is directly felt in the interfacial sub layer which is the layer of within and just above the roughness elements comprising the land or sea surface. In this layer, molecular diffusion is an important process by which heat and mass are exchanged between the surface and the air.

In particular, over land the structure of atmospheric boundary layer is strongly influenced by the diurnal cycle of surface heating and cooling, and by the presence of clouds. The unstable stratified atmospheric boundary layer or convective boundary layer occurs when strong surface heating produces thermal instability or convection in the form of thermals and plumes, and when upside-down convection is generated by cloud-top radiative cooling. In strongly unstable conditions by surface heating, the outer layer is dominated by convective motions and is referred to as the mixed layer.

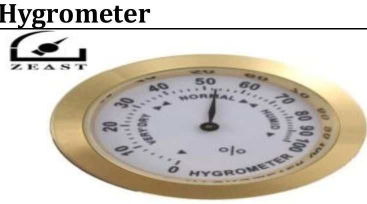
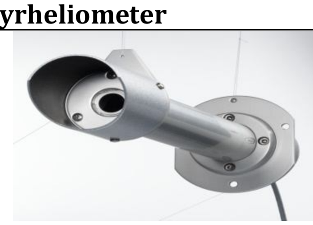
According to Jacobson, 1999(2) during the day, the boundary layer is characterized by a surface layer, a convective mixed layer and an entrainment zone. The surface layer is a region of strong wind shear that comprises the bottom 10% of the boundary layer. Since the boundary layer depth ranges from 500-3000m, the surface layer is about 50-300m thick.. Over land during the day temperatures decrease rapidly with altitude in the surface layer but less so in the mixed layer. In the surface layer, the strong temperature gradient is caused by rapid solar heating of the ground. The temperature is usually so strong that the surface layer is unstably stratified, and air adjacent to the ground buoyantly rises to the mixed layer. The mixed layer is neutrally stratified, thus, parcels of air can mix up or down. When a high pressure system is present, the top of the mixed layer is affected by a large-scale subsidence inversion which is stably stratified. Thermals originating in mixed layer cannot easily penetrate through the inversion. Some mixing (entrainment) between the inversion and mixed layer does occur; thus the inversion layer is an entrainment zone. Other features of the day time boundary layer are the cloud layer and sub cloud layer.

A region in which clouds appear in the boundary layer is the cloud layer and a region underneath is the sub cloud layer. A cloud forms if rising air in a thermal cools sufficiently. An inversion may prevent the thermal from rising past the mixed layer. During the night, the surface cools radiatively, causing temperatures to increase with height from the ground and creating a surface inversion. Cooling at the top of the surface layer cools the bottom of the mixed layer, increasing the stability of the mixed layer at its base. The portion of the day time mixed layer that is stable at night is the stable (nocturnal) boundary layer. The remaining portion of the mixed layer, which stays neutrally stratified, is the residual layer.

Because thermals do not form at night, the residual layer does not undergo significant changes, except at its base. At night, the nocturnal BL stabilizes and thickens, eroding the residual-layer base. Above the residual layer, the large scale subsidence inversion remains. Over the ocean, the boundary layer is influenced more by large-scale pressure systems than by thermal or mechanical turbulence. Since the temperature of the water does not change significantly during the day, thermal turbulence over the ocean is not as important as over land. Since the ocean surface is relatively smooth, mechanical turbulence is also less than over land.

DIFFERENT INSTRUMENTS FOR ABL STUDIES

Different instruments will be used for the ABL studies , which are insitu measurements and remote measurements. Insitu measurements like Cup Anemometer ,Hygrometer, Resistance thermometer etc., these sensors will be mounted on a tower to collect the data. Remotely measuring instruments like SODAR, Lower atmospheric Wind Profiler , LIDAR etc., Satellite based measurements such GPS RO technique. GPS satellites

1. Anemometer	**2. Barometers**
	
3. Evaporimeter	**4. SODAR**
	
5. Hygrometer	**6. Pyrheliometer**
	

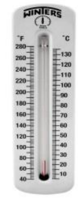
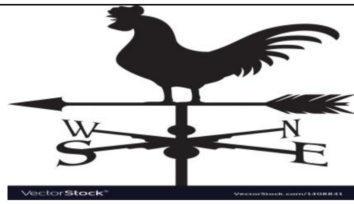
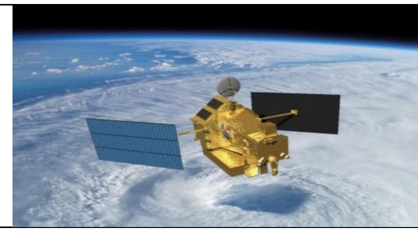
7. **Rain Gauge**	8. **Thermometer**
	
9. **Weather Wane**	10. **TRMM Satellite**
	

Figure: 3. Different Instruments to measure meteorological parameters

are primarily measuring using for positioning and navigation . The GPS satellites emits radio signals at L1 (1.57 GHz) and L2 1.22 GHz). A low earth orbit satellite contains an RO instrument and observes GPS satellites in the limb. As the density varies with height in atmosphere which will refract or bent the GPS signal. This bending signal magnitude and angle depends on the refractivity gradient of the atmosphere GPS Radio occultation (Photo :PlanetiQ) . A constellation of satellites COSMIC using GPS TO technique provides radio refractivity information with global coverage. Radio occultation technique on satellite, gives a global studies on ABL.

INDIAN MONSOON

The monsoon system of the Indian sub-continent (Lal,2003) differs considerably from that of the rest of Asia. The centres of action, air masses involved, and the mechanism of precipitation of the Indian monsoons are altogether different from other monsoon systems. Although .pseudo-monsoons or monsoonal tendencies develop over other parts of the world, it is only around the Indian Ocean that monsoonal circulation in the true sense of the term is observed. Here, the monsoons "*appear as truly massive interruptions and reversal of the normal global atmospheric circulation*."

According to Byers, Indian monsoon is the ideal monsoon where differential heating of land and ocean subjected to the annual latitudinal cycle of the Sun at its zenith gives rise to immense seasonal wind regimes. However, the mechanisms of Indian monsoons are not as simple as they are thought to be. The main reason for this very strong development of monsoons is the vast size of the Indian Sub Continent and adjacent seas. The very high and extensive mountain system of the Himalayas to the extreme north of the sub-continent is another favourable factor. The east-west alignment of this mountain chain forms a formidable physical barrier between the tropical and polar air masses, which is of great meteorological significance.

India has two important monsoons namely south--west and north-east where maximum amount of precipitation is received in almost in all parts of the country.

Are Cities Changing Local And Global Climates?

New evidence from satellites, models, and ground observations reveal urban areas, with all their asphalt, buildings, and aerosols,? are impacting local and possibly global climate processes.

India is one of the largest developing countries in South Asia and the second most populated in the world (WHO, 1992). The 1991-2001, censuses reveal an increase in population from 843 million to 1027 million and this growth is invariably seen in the urban areas. The Hindustan Times (2004) in ifs recent survey reported 8-10% annual growth of motorized vehicles in mega cities of India leading to severe traffic congestions and concomitant air pollution problems. The main cause of these air pollution related problems in mega cities is rapid economic growth through urbanization. The World Health Organization (WHO) has recently estimated that 1.4 billion urban residents in the mega cities breathe air exceeding the WHO air quality guidelines. In mega cities, such as Delhi, Mumbai, Calcutta, Chennai, Karachi and Dhaka in South Asia, and Bangkok, Beijing, Shanghai, Jakarta and Manila in East Asia, the pollution levels often exceed the WHO air quality guidelines by a factor of 3 or 4 (Faiz and Strum, 2000, orld Resource Institute, 1992,1998).

The most affected region is the developing world, where, the steadily increasing vehicle fleets, with poor emission and maintenance standards, 28 has become a significant contributor of transport-related pollutants in the urban environment (Strum, 2000 (96)). Industrialization and urbanization have a profound impact on the local climate. Gaseous and particulate pollutants modify the climate through changes in radiation balance. Atmospheric boundary layer is the region of the atmosphere where the human activities are found to be at its peak with all possible means of livelihood. The mechanical and thermal forcing will interact with r the atmosphere on meteorological scales of varying horizontal and vertical extent (Orlanski 1975 ,Vukowich 1976).

The urbanization coupled with industrialization affect the climate of lower part of the atmosphere i.e., atmospheric boundary layer. The meteorological parameters like temperature, relative humidity, mixing ratio, wind speed and wind direction play an important role in understanding the atmospheric boundary layer and its impact on urban climate and pollution concentration in mega cities.

CONCLUSION:

The behaviour of atmospheric boundary layer is different during South-West and North- East monsoon.

During south-west monsoon due to high temperatures in summer the convective processes are responsible for the transport of heat and moisture from surface to the atmosphere above. They are among the major factors, which bring variability in the weather.

During north-east monsoon in winter season high concentrations of pollutants are observed in mega cities of India, since less solar radiation is received by the sun and due to this situation the pollutants are trapped in the boundary layer and hence affect the weather and climate in the atmospheric boundary layer.

Hence the characteristics of atmospheric boundary layer are studied by analysing the diurnal variation and vertical structure of temperature, relative humidity, mixing ratio, wind speed and wind direction during south-west and north-east monsoon seasons.

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