What is the boundary layer?

The atmospheric boundary layer is the part of the atmosphere that is directly influenced by the land surface. It stretches from the ground to typically between 50m and 2km. It plays an important role in driving weather variation and the dispersion of atmospheric pollution.

How does it form?

The boundary layer exists because of the interaction between the atmosphere and the Earth’s surface. In the free atmosphere above the boundary layer, there isn’t much turbulence (chaotic flow). But because the ground is rough (mountains, hills, forests, cities...) air movement often becomes restricted. When air is restricted it starts to move in a more chaotic way. Think of the difference between a rocky, shallow stream and a wide, deep river; the rocks are the rough surface layer and the water is the air. Because the rocks are pushing the water out of the way, the movement of the water in the stream is much more complex than it is in the steady uninterrupted river.

Turbulence is also caused by heat. When the surface is heated, it starts to heat the air, causing the air to rise rapidly. This swirling air is what you see over tarmac on a hot day. When the surface is warmer than the air, the boundary layer is turbulent and unstable. When the air is warmer than the surface there is less turbulence; the boundary layer is more stable and the air is less well mixed.

Boundary layer daily cycle

During the course of a typical 24 hours, the heat of a surface changes largely because of the influence of sunlight. During the day, the surface becomes warmer, reaching a maximum temperature during the afternoon. This heating drives turbulence in the boundary layer, causing it to become more unstable and increase in height. When the sun goes down, the surface starts to lose heat and the boundary layer becomes less turbulent (more stable) so it decreases in height. Variations in the height and stability of the boundary layer are influenced by cloud cover and wind speed so in one location no two days are quite the same in terms of predicting the behaviour of the boundary layer.
The urban boundary layer.

The boundary layer is affected by urban areas. The urban heat island effect means that the city is usually warmer than its surroundings, particularly overnight. In addition to this heating, buildings of various sizes make the urban surface very rough. Both of these things can make an urban boundary layer higher during the day than you might expect from the surrounding countryside. Also, as the city cools less overnight, and takes longer to cool, the night time boundary layer can be less stable than in rural areas and take longer to become stable.

These things could have negative effects on the spread of pollution. Depending on weather conditions, the urban boundary layer might rise over the top of the rural one (this is called an urban plume). The urban plume transports pollutants and heat downstream of the city. The implication of this depends on the conditions, but where the city is hot enough to produce strong thermal air flows upwards, pollutants can be transported up high and out of the city. Later they are recirculated back into the city at low level over the surrounding countryside. In these conditions the city cannot be rid of its pollutants.

Why is it important?

We live in the boundary layer, we directly influence it and it influences our environment. Monitoring of the boundary layer in urban areas is important for the following applications:

- Air quality monitoring. The flows within the boundary layer control the movements of pollutants. An unstable boundary layer mixes pollutants higher into the atmosphere (lower concentration measured) whereas a stable boundary layer traps them closer to the surface (higher concentration measured).
- Energy and heat efficiency. Monitoring and modelling of wind flow (applications in renewable wind energy) and heat flow (integral to efficient building design).
- Weather forecasting. The variation in the boundary layer drives variation in weather conditions, particularly of winds and cloud cover. Research into the accurate representation of boundary layer processes in weather forecast models is current and on-going.
- Weather hazard warning. Boundary layer processes are key to furthering the understanding of weather hazards such as tornados, thunderstorms and fog.
- Climate prediction. Failing to account for boundary layer processes reduces the accuracy of climate models.

**ACTUAL (Advanced Climate Technology Urban Atmospheric Laboratory) is funded by the UK Engineering and Physical Science Research Council (EPSRC.)**

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