THE BOUNDARY LAYER - Air Near the Ground

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Abstract

The most important portion of air in the atmosphere is a thin layer immediately in contact with the Earth's surface known as the Surface Layer. It is within a deeper region known as *the Boundary Layer*. The Surface Layer is the region of energy and moisture interchange between the lithosphere and the atmosphere and understanding its dynamics is crucial to understanding atmospheric changes. Not enough attention has been paid to these dynamics because the concern is global and at least regional climate. True understanding of larger scales is only as adequate as the measures and knowledge of microclimates.

Introduction

The world's temperature is officially defined by measures taken in a Stevenson Screen.

Source: http://en.wikipedia.org/wiki/Stevenson_screen

This is incorrectly called the surface temperature. Actually it is the temperature between 1.25 m (4 ft 1 in) and 2 m (6 ft 7 in) above ground, the standard range set by the World Meteorological Organization (WMO). So

the global average annual temperature is only the temperature within a 75 cm layer. Variations in the temperature provide a relative measure of changing conditions, but that is all. It is much more difficult to determine the cause of the change.

The 75 cm layer is generally within a dynamic area known as the Planetary Boundary Layer (PBL). This is a layer of liquid or gas immediately at the interface between two surfaces. Wikipedia defines it as follows; *In the Earth's atmosphere, the planetary boundary layer is the air layer near the ground affected by diurnal heat, moisture or momentum transfer to or from the surface.*

http://en.wikipedia.org/wiki/Boundary_layer

Within the PBL there is another zone known as the Surface Layer, generally defined by the depth of turbulence. This varies with the strength of the wind. Generally, the Stevenson Screen is in this layer, but it can also be above it depending on wind speed.

Microclimate Weather Stations

Traditionally a weather station recording data right at the surface was known as a microclimate station. There are very few of these most being associated with specific research projects such as the following.

http://research.eeescience.utoledo.edu/lees/research/TEF/TEFdata/microclimate/microclimateindex.html

http://polaris.nipr.ac.jp/~penguin/polarbiosci/issues/pdf/1991-Ohtani.pdf

Most of the projects involve vegetation and a specific area of agricultural meteorology developed.

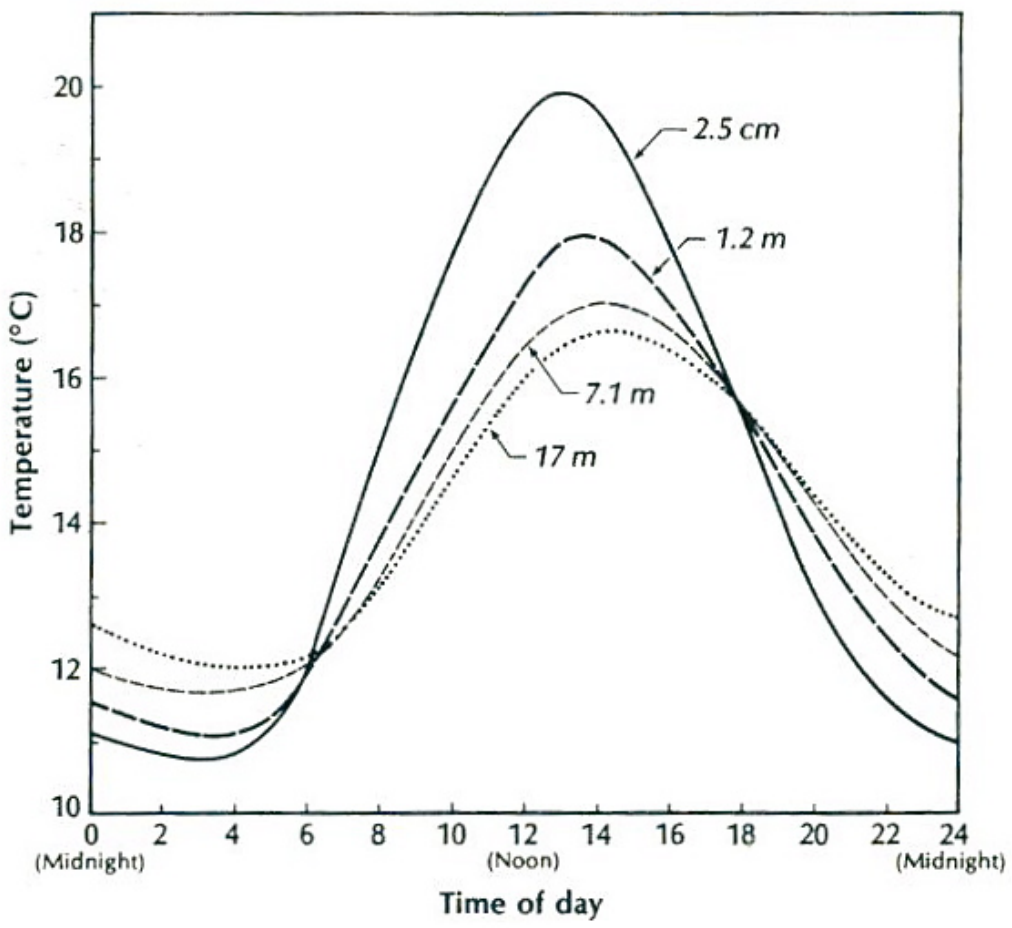
Certain books in climate have justifiably become classics. Likely least known of these is the 1927 book “Climate Near the Ground” by Rudolf Geiger. It is currently in a sixth edition. A version is available here;

http://ia331304.us.archive.org/0/items/climatenearthegr032657mbp/climatenearthegr032657mbp.pdf

It was a remarkable work that remained the major source until well into the 1960s. It should be required reading for anyone trying to understand global climate because it literally examines it from the ground up.

Another important work was *Physical Climatology* by W.D.Sellers published in 1965. A more recent book of considerable influence was *Boundary Layer Climates* by T. R. Oke, (1987).

Here is a diagram from Geiger showing his measures of the difference in temperature with height above the ground.



Source: *Climatology*, Oliver and Hidore. Data from Geiger.

High and low temperatures are greater and therefore the range of temperature is greater.

Specific Differences
What goes on right at the surface that makes it essential to understanding conditions in the atmosphere above?

Energy
The most important function is the absorption of incoming solar radiation (insolation) and conversion to longwave radiation (low energy infrared). It is this energy that heats the atmosphere.

Moisture
A portion of the energy is used to evaporate moisture. This energy is not lost but is transported into the atmosphere where it is later released.

Other Gases
Most atmospheric gases originate from the surface and therefore their concentration is higher in the first few centimeters above the ground. Their effect on radiation is greater here than almost anywhere in the atmosphere.

Particulates
Particles or fine material in the atmosphere originate at the surface. The two most important types are salt particles over the ocean and fine clays over the land. These are important because without them much water vapor (gas) will not condensate into water droplets (liquid). They also absorb solar energy thus heating the atmosphere directly.

Air Movement
Air molecules in direct contact with the ground are heated by conduction. Once heated, they become mobile and rise in a process called convection – a vertical movement of air. This, with evaporation, is the major process that heats the atmosphere.
The rising air reduces the density of molecules creating low pressure. Surrounding air has relatively higher molecular density or high pressure. Air moves from high to low. Technically this is advection, but commonly called wind. It is an important process right at the surface because it removes heated molecules and replaces them with cooler ones thus increasing the rate of conduction. It also increases the rate of evaporation as saturated air right at the surface is replaced by less saturated air.

This is a very cursory overview of the different conditions that exist below the official height at which the atmosphere is measured. Early in my career I

was involved with attempts to design a microclimate station. Limits were set by lack of instrumentation, especially for measuring vertical and horizontal air movement. A climate researcher recently told me of his experiences over the sea surface. He wrote; *I wasted the first three years of this decade living on a boat so I could try to measure the energy interactions at sea surface, and I failed. The matter is extremely complex, and my failure was a result of effects of ripples (n.b. ripples, not waves) that I do not think had been previously detected… I wasted three years of my life only to learn that there are no existing methods capable of quantifying surface/air energy interactions over the sea (i.e. 70% of the Earth's surface).*

How do researchers deal with the limitations of insufficient or inadequate data of surface layer conditions when building computer models? Here is the definition and explanation from the National Oceanographic and Atmospheric Administration (NOAA).

http://www.esrl.noaa.gov/psd/psd3/pbl/surface.html

Parameterizations are mathematical simplifications of physical processes. The term parameterization usually refers to a simple mathematic formula expressing some desired variable in terms of other parameters of the system that are known through measurement or are "realized" within a model. Parameterizations are normally used when a variable is of interest only internally to a model, or the process is so complicated it can only be practically represented statistically, or we lack an essential measured property and must estimate it from properties that are measured.

Parameterizations are developed through high resolution observation and model validation. ETL has developed parameterizations for turbulent and radiative fluxes at the surface.*

Since we do not have “an essential measured property” it is parameterized in the computer models. The question is what are the “high resolution observations and model validation”? It is possible to simulate some surface conditions, but there are an almost infinite variety and they are very dynamic. A measure of the variety is provided by the dominance of microclimate studies under, over and within vegetation in the few that are done especially for agricultural crops.

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Many microclimate studies involve crops, because Stevenson Screens are above their growing area. An illustration of the problem of this difference occurred when the Saskatchewan government established a frost insurance program. Farmers could choose the weather station used for evidence of frost. In the very first year a hard frost occurred on August 20. Crops were still green and farmers over large areas reported frost blackened crops. A majority of them received no compensation because the Stevenson Screen temperature showed a low temperature of 0.5°C.

This is a very brief introduction to the most important layer of air immediately at the surface. It refers to but does not include any discussion of the variety of surfaces that exist or how they change from hour to hour, day to day, season to season and year to year. This is important because the Intergovernmental Panel on Climate Change (IPCC) identify human changes to surface conditions as a factor in climate change.

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