Numerical simulation using digital computers has been very popular since the 1960's, with many discoveries that were verified years later with field studies. Most of these computer simulations employ the stochastic method of modeling fluid flow. Unfortunately, a difficulty known as the ***closure problem*** has meant that each of these models has at best been able to only approximate the governing equations, with uncertainties introduced via a necessary parameterization of the unknowns.

That same closure problem has limited the avenues for ***theoretical studies*** involving analytical solutions. For the most part, only highly simplified approximations to the boundary layer have been amenable to direct solution.

If anything, these difficulties have stimulated, rather than stifled, the work of micrometeorologists. There is an underlying assumption in meteorology that subsynoptic-scale phenomena such as turbulence might be responsible, in part, for the difficulty in making quality weather forecasts beyond a few days. Thus, part of the effort in boundary layer meteorology involves the search for adequate turbulence parameterization schemes for larger-scale numerical forecast models.

Additional motivation has come from concern over our environment. Every species of animal and plant modifies its environment; the human species, however, is in a position to recognize the consequences of its pollution and take appropriate action. Since most of the anthropogenic effluents are emitted from near-surface sources, the resulting dispersion of the pollutants is tied to boundary layer processes. As a result, ***air-pollution meteorology*** is an applied form of micrometeorology.

Other applications include ***agricultural meteorology***, where airborne transport of chemicals necessary to plant life is governed by turbulence. Nocturnal processes such as frost formation warrant improved study and forecast methods for crop protection. Fog and low stratocumulus, which inhibit aviation operations, are essentially boundary layer phenomena. Wind-generated power, a popular energy source for centuries, has had a recent increase in interest as wind turbines have been designed to extract energy more efficiently from the boundary layer wind. Other structures such as bridges and buildings must be designed to withstand wind gusts appropriate to their sites.

1.8 Significance of the Boundary Layer

The role of the boundary layer on our lives is put into perspective when we compare the characteristics of the boundary layer and free atmosphere (Table 1-1). A taste of the importance of the BL is given in the following summary:

- People spend most of their lives in the BL.
- Daily weather forecasts of dew, frost, and maximum and minimum temperatures are really BL forecasts.
- Pollution is trapped in the BL.
- Fog occurs within the BL.
- Some aviation, shipping, and other commerce activities conducted within it.
- Air masses are really boundary layers in different parts of the globe that have equilibrated with their underlying surface. Baroclinicity is generated this way.

Table 1-1. Comparison of boundary layer and free atmosphere characteristics.

Property	Boundary Layer	Free Atmosphere
Turbulence	• Almost continuously turbulent over its whole depth.	• Turbulence in convective clouds, and sporadic CAT in thin layers of large horizontal extent.
Friction	• Strong drag against the earth's surface. Large energy dissipation.	• Small viscous dissipation.
Dispersion	• Rapid turbulent mixing in the vertical and horizontal.	• Small molecular diffusion. Often rapid horizontal transport by mean wind.
Winds	• Near logarithmic wind speed profile in the surface layer. Subgeostrophic, cross-isobaric flow common.	• Winds nearly geostrophic.
Vertical Transport	• Turbulence dominates.	• Mean wind and cumulus-scale dominate
Thickness	• Varies between 100 m to 3 km in time and space. Diurnal oscillations over land.	• Less variable. 8-18 km. Slow time variations.

- The primary energy source for the whole atmosphere is solar radiation, which for the most part is absorbed at the ground and transmitted to the rest of the atmosphere by BL processes. About 90% of the net radiation absorbed by oceans causes evaporation, amounting to the evaporation of about 1m of water per year over all the earth's ocean area. The latent heat stored in water vapor accounts for 80% of the fuel that drives atmospheric motions.
- Crops are grown in the BL. Pollen distributed by boundary layer circulations.
- Cloud nuclei are stirred into the air from the surface by BL processes.
- Virtually all water vapor that reaches the FA is first transported through the BL by turbulent and advective processes.
- Thunderstorm and hurricane evolution are tied to the inflow of moist BL air.
- Turbulent transport of momentum down through the BL to the surface is the most important momentum sink for the atmosphere.
- About 50% of the atmosphere's kinetic energy is dissipated in the BL.
- Turbulence and gustiness affects architecture in the design of structures.
- Warm and cold fronts separate boundary layers of different temperature.
- Wind turbines extract energy from the BL winds.