BLTURB
Scientific Description

Background

All aircraft fly in the atmospheric boundary layer at some time during their flight. The atmospheric boundary layer is the layer of air in which the affects of the earth's surface are felt directly (Garratt 1992). Its height is usually about the lowest kilometer above ground level (AGL) but can be as high as 4 km AGL or as low as barely above the surface. On sunny or windy days turbulence in the boundary layer is ubiquitous. Turbulence anywhere in the atmosphere may be strong enough to cause pilots to lose aircraft control which near the ground may result in a crash.

The most common approach to account for turbulence is to estimate its energy. Turbulent kinetic energy (TKE) equations follow from the equations of motion and continuity. By making

$$\varepsilon = K_m \left(\frac{\partial v}{\partial z} \right)^2 - K_h \frac{g}{\Theta} \frac{\partial \Theta}{\partial z}$$

reasonable assumptions and ignoring small terms, a simple TKE equation may be derived: where ε is the TKE dissipation, v is the mean wind at some level z above the ground, g is the acceleration of gravity, and Θ is the mean potential temperature. K_m and K_h are eddy diffusivities for momentum and heat. See Garratt (1992) and McCann (1999) for derivation details. On the right hand side are the TKE production terms. Because the vertical wind shear term is squared, any change in the wind with height will produce positive TKE. The second production term will only be positive when the potential temperature decreases with height, i.e., a superadiabatic lapse rate. Buoyancy production is negative in stable conditions and many times will offset positive wind shear production and suppress the turbulence. When TKE production is negative, there is no TKE to dissipate, so TKE dissipation is set to zero.

TKE dissipation describes the molecular process that turns turbulence into heat. In order to apply the TKE equation to the aircraft turbulence problem, one has to assume that the turbulence dissipation cascades from larger turbulent eddies. Since aircraft respond only to a range of eddy sizes (The range depends on individual aerodynamic performance factors), they cannot feel turbulence from small eddies and will ride smoothly within very large eddies. In fact, a pilot reporting plus-and-minus low level wind shear is likely experiencing a very large turbulent eddy (Arkell 2000). In spite of these potential problems, McCann (1999) showed a positive correlation between TKE production/dissipation and pilot report turbulence intensity in the boundary layer.

The BLTURB algorithm

BLTURB takes model sounding data and computes boundary layer TKE production/dissipation. This section will describe the details on how BLTURB calculates its output.

For each forecast time, BLTURB first finds the model surface height, temperature, and wind. Once surface data are found, BLTURB begins reading model height, temperature, and wind above the surface one level at a time. It computes the vertical difference of wind and potential temperature then plugs them into the TKE equation using K_m as derived in McCann (1999) and $K_h = 4K_m$. Because some numerical models have problems with surface temperature forecasts, BLTURB only allows $\partial\Theta < -1.2$C so the lapse rate cannot be unrealistically superadiabatic. Without this limitation BLTURB tended to overforecast the turbulence, especially in high terrain. If $\varepsilon < 0$, then that level is the top of the boundary layer, and from that level upward $\varepsilon = 0$. Otherwise, BLTURB continues upward until it reaches the boundary layer top.

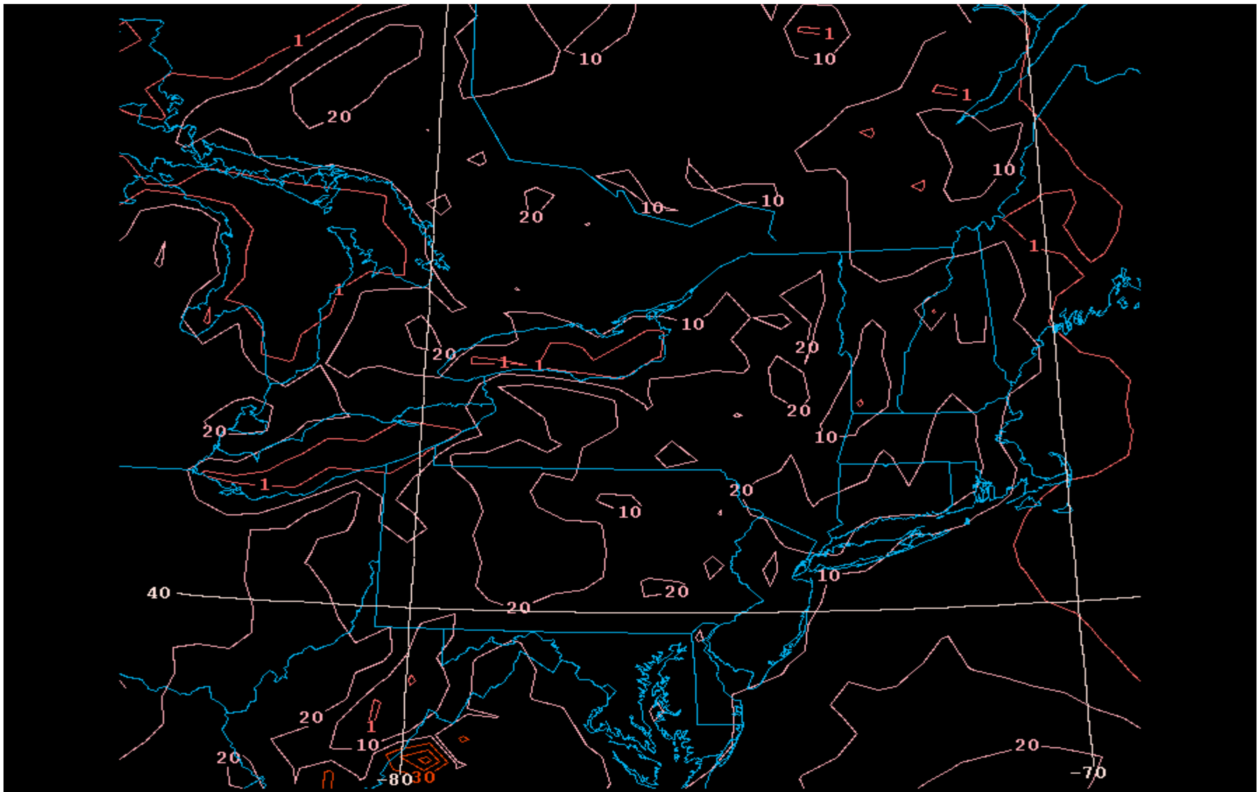
Operational interpretation

BLTURB only computes boundary layer turbulence. By definition the boundary layer top is the top of the boundary layer turbulence. It is possible that another kind of turbulence exists above.

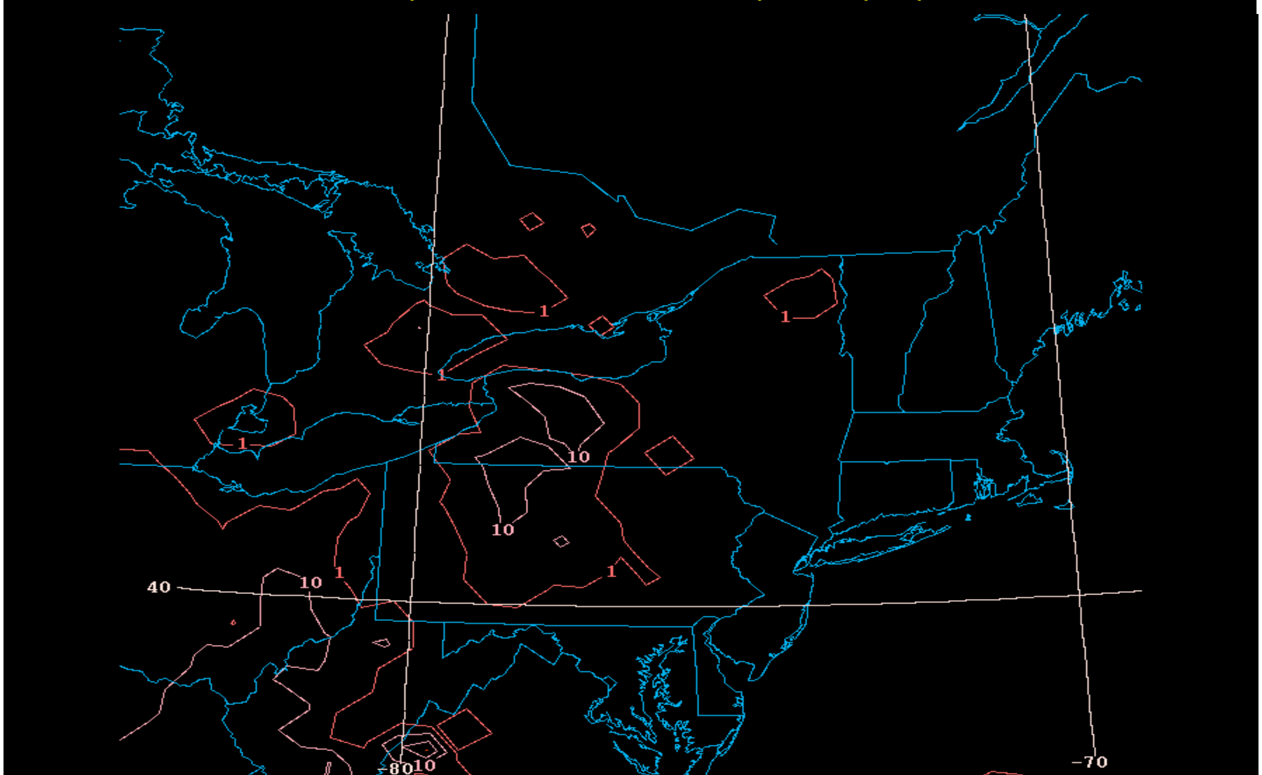
McCann (1999) computed TKE production/dissipation in 2759 aircraft turbulence pilot reports of all intensities. The table below shows the TKE production/dissipation thresholds that yielded the best verification for LIGHT, MODERATE, and SEVERE turbulence.

Smooth/Light	.000 j sec^{-1}
Light/Moderate	.016 j sec^{-1}
Moderate/Severe	.035 j sec^{-1}

The following figures show displays of BLTURB TKE production/dissipation computed from the RUC2 model's one hour forecast from 1500 UTC, 31 March 2003. Units are 10^3 joules per second. The first is in the 900:925 mb layer or about 2000 feet above sea level. The second is in the 800:825 mb layer of about 6000 feet above sea level. Note the decrease in TKE production/dissipation with height.



030331/1600V001 900 : 925 MB TKE (10**-3 J/sec)



030331/1600V001 800 : 825 MB TKE (10**-3 J/sec)

References

Arkel R.E., 2000: Differentiating between types of wind shear in aviation forecasting. *Natl. Wea. Digest*, **24(3)**, 39-51.

Garratt, J.R., 1992: *The Atmospheric Boundary Layer*, Cambridge University Press, 316 pp.

McCann, D.W., 1999: A simple turbulent kinetic energy equation and aircraft boundary layer turbulence. *Natl. Wea. Digest*, **23(1,2)**, 13-19.