BLIPMAP Parameter Information

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Updated 14 May 2006

General Principles:

Because models have biases, they are better at predicting changes than precise values, so: **for all parameters, relative predictions are more reliable than absolute predictions.** Here "relative" means relative in time, relative in space, and relative to the model topography.

Thermal prediction parameters:

Thermal Updraft Velocity (W*)

The program's method of estimating thermal strength is unique within the soaring community, to my knowledge, and so will be discussed in some detail. Note that this prediction is intended to forecast the upward velocity of *air* within the thermal and will never be negative - so the glider descent rate while thermalling must be subtracted to give the expected variometer reading.

It has been established, both theoretically and experimentally, that vertical turbulent motions in a *cloud-free* convective boundary layer are proportional to the convective velocity W* ("w star"), defined as $W^* = [\,(g/T_o)\, Q_s\, D\,]^{1/3}$ where D is the boundary layer depth (or thermal depth), Q_s the surface heating, and (g/T_o) a known buoyancy constant (obtained by dividing the earth's gravitational acceleration g by the average temperature T_o). W* *inherently* has units of velocity - this is not a coincidence, but rather an integral consequence of the theory predicting W* to be a governing parameter. Physically, it should be reasonable that a thermal's strength will depend upon the amount of heat entering into the atmosphere at the ground - and the thermal height is an important factor because a rising thermal bubble will achieve a higher velocity if it accelerates for a longer time. The needed factors of BL depth and surface heating are predicted by a numerical model. There is still an unknown proportionality constant relating W* to the vertical velocity in a thermal actually experienced by a glider, but by theory that constant is *not* completely arbitrary - it should be approximately one, with the exact value depending upon such factors as the area over which the vertical velocity is averaged (since a thermal's core is stronger than its periphery) and thus will depend upon the thermalling radius of the glider, for example. For now I have simply set this proportionality factor to one and it is gratifying to find that *without having to resort to any empiricism whatsoever* the predicted vertical velocities are quantitatively very realistic. With further experience the proportionality constant might be adjusted slightly, but the present results are considered very reasonable, given that a range of thermal strengths occur at any one time and that vertical velocity of a thermal will vary both with height and with distance from the core. And besides, W* - like all model parameters - is best evaluated relatively than as an precise value. W* follows the pilot's rule that deep thermals tend to be strong thermals, but also includes the influence of surface heating.

Note: This parameter assumes that buoyancy results solely from surface heating - but if convective clouds are present then additional buoyancy will be released aloft by condensation heating, increasing thermal strengths above those obtained from this formulation [see the Neglected Cloud Effects section below]. (However, it does include the often minor effect of *surface* humidity on buoyancy.)

Buoyancy/Shear Ratio (B/S)

A shortcoming of the BL top (TI=0) height prediction is that it indicates the height to which mixing will occur but not all mixing is equally useful to glider pilots. Mixing can be produced both by thermals and by (vertical) wind shear, but only thermals produce the relatively large updrafts needed for soaring. To help evaluate the degree to which the day's mixing is convectively driven, a thermal "hot air" parameter "B/S" (sic) represents the ratio between Buoyancy and Shear production of turbulence. A small B/S value indicates wind shear, due to wind changing with height, is likely a significant problem - at present the best guidance I have, based upon sailplane pilot reports, is that on days with B/S of 5 or less the thermals are likely to be too broken to be usable - hang gliders and paragliders, who are able to turn in smaller circles, seem to be able to thermal in smaller values, based on a few reports I have received. At a B/S of 10 or above, vertical shear is likely not a significant factor. Note that only a single value is provided, representing the BL as a whole, whereas B/S normally decreases closer to the surface.

For those interested in more scientific detail, the B/S ratio is *not* per se an empirical approach but is based upon the non-dimensional number used to distinguish between "buoyancy dominated" and "shear dominated" BLs (and those in between). It is the ratio of the "buoyant production of turbulent kinetic energy" to the "shear production of turbulent kinetic energy" with both being well defined terms. However, the cross-over criterion between "workable" and "unworkable" thermals must be determined empirically (and for that matter there is no sharp cut-off between the two cases).

Note: This parameter assumes that buoyancy results only from surface heating - if convective clouds are present additional buoyancy will be released aloft by condensation heating, increasing W* above that used for this calculation and thus increasing the actual B/S ratio above that predicted [see the Neglected Cloud Effects section below].

Height of Boundary Layer Top (TI=0 height)

This parameter could also be called the height of the *Mixing Layer*, i.e. the height to which turbulence created by the surface mixes the atmosphere above it. This turbulence and mixing can be generated by either heating of the ground, producing relatively large-scale eddies called thermals, or by the interaction of the wind with the solid surface, producing smaller-scale eddies through vertical wind shear (also known as "mechanical turbulence"). The resulting mixing height, or BL height, is here obtained by (essentially) computing the height where the Dry Adiabatic Lapse Rate (DALR) through the surface temperature intersects the temperature profile. [More precisely, it is where the *virtual potential* temperature equals that at the lowest RAP model grid point, where virtual potential temperature compensates for effects of both moisture and pressure. Speaking as a BL meteorologist, I should note that this definition is used because it matches that employed by the RAP model but is somewhat ad hoc and is *not* the best estimate of a convective BL top.] This is essentially the height where the "Thermal Index" (TI) is zero.

When thermals exist they create a convective BL and the thermal tops create the BL top. Over flat terrain a glider is not expected to actually reach the thermal tops since the glider has a sink rate. However, over complex terrain pilots tend to fly peaks of small-scale topography which is not resolved by the model's smoothed topography - there the BL tops will be higher than over the grid-averaged surface elevation so maximum thermalling heights can reach or exceed the BL top based on a smoothed topography. The relationship of the BL Top to the BL temperature profile and to Hcrit is depicted in the diagram at Convective BL Profiles and for a more detailed description see The Convective Boundary Layer and Sounding Analysis

Note that when vertical wind shear is strong (due to wind varying with height), or convection weak, the BL top then results from small-scale mixing caused by wind shear rather than from thermals. In such cases the "BL height" will be misleading to the naive user, since small-scale eddies cannot support a glider so such a BL height has little relationship to the height that a glider will reach, though smoke released from the ground *would* be expected to eventually reach that height. In such cases the "Buoyancy/Shear Ratio" parameter will be small, so one should be wary of utilizing this parameter under those conditions - the Height of Critical Updraft Strength parameter, on the other hand, remains more trustworthy in such cases because it includes W* in its formulation.

The BL top height is also affected by vertical motion caused by convergence/divergence lines [see BL Max. Up/Down Motion below], but this effect is under estimated because model grid *horizontal* spacing is too coarse to accurately predict the convergence, hence the computed vertical motions are smaller than actual values.

Note: In the presence of clouds the thermal top will increase, but the maximum thermalling height will then be limited by the cloud base [see the Neglected Cloud Effects section below].

Height of Critical Updraft Strength (Hcrit)

This parameter estimates the maximum thermalling height over *flat* terrain under cloudless conditions. Hcrit is obtained from an averaged profile of thermal updraft velocity vs. height (obtained from research aircraft measurements by Lenschow and Stephens) by assuming that the maximum updraft velocity in the BL depends upon the thermal strength W* and computing the height at which the updraft velocity drops below 225 fpm (as a rough estimate of the sink rate of a sailplane or hang glider actively turning and maneuvering to remain with in a thermal). The intent is to obtain a better estimate of the maximum thermalling height than is provided by temperature-based criteria such as the "Thermal Index", since the latter was intended for use with morning soundings (prior to thermal heating) and no meaning for an afternoon sounding and since upward motion is what actually supports a glider. *But the present formulation makes several assumptions and is subject to bias and has not yet been quantitatively tested - so its predictions are are better evaluated relatively than as absolute values.* If, after evaluation over many flying days, you find there is a systematic bias in Hcrit for your location I would like to hear about it as the assumptions made might then be slightly altered to better improve the quantitative predictions. (Since BL Top tends to <u>over</u>predict the maximum thermaling height, I purposely used Hcrit assumptions which would, if anything, <u>under</u>predict the max. thermaling height - so the max. thermaling height would then tend to be bracketed by BLTop and Hcrit.) Note that if W* is less than 225 fpm then Hcrit is predicted to be the surface. Hcrit is compared to the BL top and W* in the diagram at Convective BL Profiles. Because this parameter incorporates the value of W*, it is less subject to the high wind speed interpretation problems already described for the Height of Boundary Layer Top parameter.

Note: In the presence of clouds the maximum thermalling height may instead be limited by the cloud base [see the Neglected Cloud Effects section below].

Thermal Height Variability

This parameter measures the atmospheric stability above the BL and thereby indicates the *variability* of the BL top (TI=0) height which can arise from (1) actual variations in surface temperature over the region encompassing a model grid cell due to surface changes, etc., (2) variations in actual surface elevation which are omitted by the smoothed topography over a model grid cell (since surface elevation changes are effectively changes in surface temperature), or (3) error in the model's surface temperature prediction. The value given is the expected height change which would be produced by a surface change of 4 degF, but is usually best evaluated in a relative sense. (Numerically this parameter is calculated as the difference between the TI=+4 and TI=0 heights - strictly speaking this only give the effect of an increase in surface temperature, since the effect of a surface temperature decrease cannot be easily estimated.) Weak stability above the BL top gives large variability values which are often good for soaring, since thermal heights due to small sub-grid-scale variations can then be much higher than the predicted average BL height. However, high variability values can also be accompanied by soaring conditions being much poorer than those predicted if actual surface temperatures are much cooler than those predicted by the model. In short, this parameter represents the uncertainty of the predicted BL height. [see the BL Variability diagram].

Wind prediction parameters:

Wind Speed in the Boundary Layer

The magnitude of the wind vector computed by averaging the wind *vector components* through the BL depth. Note that this is *not* the same as simply averaging the windspeed at all levels, since the vector averaging allows opposing wind directions to cancel each other out. For example, this parameter would be zero if the wind in the upper and lower halves of the BL were to be directly opposed to each other. Often the wind speed does not greatly vary with height in the convective BL, in which case this parameter approximates the wind speed at flight levels - but if there is a large change in wind direction through the BL then the prediction can be misleading. For complex conditions you must look at the actual wind variation with height, as given by either a BLIP or an GSD sounding profile.

Wind Direction in the Boundary Layer

The true direction [using the meteorological convention, i.e. the direction the wind is coming *from*] of the wind vector computed by averaging the wind *vector components* through the BL depth. Note that this is *not* the same as simply averaging the wind direction at all levels - such averaging could be very misleading due to the artificial crossover between 0 and 360 degrees. Often the wind direction does not greatly vary with height in the convective BL, in which case this parameter may be expected to approximate the wind direction at flight levels - but if there is a large change in wind direction through the BL then the prediction can be misleading. For complex conditions you must look at the actual wind variation with height, as given by either a BLIP or an GSD sounding profile.

Wind Shear in the Boundary Layer

This parameter measures the *vertical* change in wind through the BL. The wind vector at the bottom of the BL is "subtracted" (in a "vector difference" sense) from the wind vector at the BL top and the magnitude (vector length) of the resulting difference vector is then plotted. BL wind shear can result from a difference in wind speed or wind direction or both through the BL - *zero* wind shear requires that the winds at the bottom and top of the BL be identical in both speed and direction. While there is of course a tendency for strong wind shear to occur when the windspeed is large, often the locations of strongest maximum wind shear will *not* coincide with maxima of BL-averaged wind speed.

This parameter measures the degree of wind variation across the full depth of the BL and thereby indicate whether a pilot should expect large changes in wind speed/direction as he changes height in the BL, say when going from the bottom of a thermal to its top. Unfortunately this parameter can be confused with what I will here call the "wind shear *gradient*", which is the *rate of change* of wind with height - for example, the BL wind shear gradient would be this parameter divided by the BL depth. The wind shear *gradient* (1) affects the production of shear (mechanical) *turbulence* in the atmosphere and (2) is also important because aircraft behavior is affected when passing through a layer with a strong wind shear gradient, as often occurs near the ground. While there is obviously a definite relationship between the two, they are nonetheless not equivalent. When creating this parameter I had to choose between presenting the net wind difference across the BL or the average wind shear gradient in the BL - I chose to use the former because latter is usually important only near the surface, not the in the BL itself, but I would re-consider that if there was a strong preference for instead depicting the average wind shear gradient.

Note that this parameter measures vertical wind shear and has nothing to do with what some pilots call a "shear line" (what I refer to as "convergence"), which results from horizontal wind shear.

BL Max. Up/Down Motion (BL Convergence)

The numerical model computes the vertical motion which occurs over each grid cell due to the horizontal convergence (or divergence) of wind into the grid volume. (Some pilots refer to the *horizontal* wind shear which produces this convergence as a "shear line", but I consider this term potentially confusing since "wind shear" most commonly refers to *vertical* wind changes, so avoid using it.) This plot is unusual in that it combines *two* parameters: the maximum *upward* motion within the BL (due to convergence) and its opposite, the maximum *downward* motion within the BL (sink, due to negative convergence, or divergence) - the one plotted at any individual location is whichever has the largest absolute magnitude, thus combing in a single plot a depiction of regions of both strong extensive upward motion and downward sink (since the two seldom overlap).

Note that convergence line dynamics occur on a much smaller scale than is resolved by the model - for example, the actual upward motion has a width on the order of 100 m compared with typical model resolutions of 12-20 km. Model convergence must be spread over a grid cell rather than the actual convergence line width, so the model will greatly under-predict the magnitude of this upward motion (this is depicted in a diagram comparing actual vs. model convergence). Another consequence of the inadequate resolution is that this parameter is often very "noisy", with "ghost convergences" appearing one hour and disappearing the next (methods of testing the reliability of forecast convergence features include comparing the "latest" prediction to the "FirstToday" prediction and examining multiple times, since if the feature does not appear consistently then it is unreliable). So BLIPMAP convergence predictions should be evaluated in *qualitative* terms, e.g. using *relative* magnitude and location differences from one day to the next - and taken with a grain of salt to boot.

For convergence lines created by topography which can be resolved by the model, RAP forecasts of this parameter *have* been found useful (see Sailplane reports on RAP convergence). Empirically, pilot experience suggests that RAP-forecast upward motions created by topography are usable for sailplane pilots when larger than 50 cm/sec. Although in theory the finer NAM resolution should produce better convergence forecasts, NAM forecasts have in practice proved less useful than RAP for terrain-induced convergence (this may result from a large amount of artificial smoothing negating the increased resolution or from inherent problems resulting from the NAM's unique vertical coordinate scheme).

So far usefulness of this parameter has not yet been established over flat terrain. Convergence lines created by sea breezes over flat terrain will be forecast, but the location of such convergence lines is particularly subject to much error since they are not anchored by topography and their movement depends upon sea breeze front dynamics which the model does not resolve. A recent hang glider report indicates that convergence forecasts have proved qualitatively useful in Florida in forecasting sea breeze convergence lines.

Cloud prediction parameters:

There is great potential to misunderstand these cloud predictions! Except for CAPE. all these parameters apply *only* to clouds which develop locally due to convection, not to clouds which move into the area or which occur above the Boundary Layer.

Cumulus Potential

This parameter evaluates the potential for formation of small, non-extensive cumulus in the BL. It is calculated as the height difference between the surface-based LCL and the BL top, with positive values being expected for cloud formation. It has the theoretical difficulty described below for the "Cumulus Cloudbase" parameter so it is possible that a criterion value of zero will *overestimate* cumulus cloud formation and that the actual threshold value is greater than zero, hence I recommend empirical evaluation of this parameter at your site prior to relying on its predictions.

Cumulus Cloudbase (Sfc. Lifting Condensation Level)

This cloudbase estimate for small, non-extensive cumulus clouds is based upon the humidity at the surface and can be called the "Lifting Condensation Level (LCL) based upon surface humidity" [Warning: the word "LCL" appear in meteorological analyses such as on soundings, but often the reference humidity on which it is based is not specified even though different humidity assumptions will give different LCL values!] It makes the simple assumption that a parcel of air rising from the surface ascends to the BL top without mixing, with cloudbase occurring where the ascending parcel reaches its dew point temperature. But mixing with environmental air does actually occur during the ascent and environmental air is generally drier than that at the surface, so the actual height of condensation would be expected to be higher than the simplified assumption would predict. Nonetheless, I have an empirical report that for some sites cloudbase does often occur at the level predicted by the simple assumption, possibly because of some offsetting behavior, and so am providing this parameter for users to evaluate at their location. But I strongly recommend empirical evaluation of this parameter at your site prior to relying on its predictions. [Note: this parameter is essentially what one obtains from the simple formula which estimates the AGL cloudbase height as 400ft (120m) times the difference between the surface temperature and the surface dew point in degC, often cited in US literature as a 4.5degF difference producing a 1000ft AGL cloudbase].

OvercastDevelopment Potential

This parameter evaluates the potential for *extensive* cloud formation (OvercastDevelopment) at the BL top, being the height difference between the BL CL and the BL top. OvercastDevelopment (extensive clouds and overcast) becomes increasingly likely with its value increase above zero. Empirical evaluation of OD Potential predictions vs. actual OD experience and use of an empirical criterion different from zero may yield better results at your location. Note that in some cases only negative numbers may appear in the colorbar legend, in which case the statement "OvercastDevelopment being increasingly more likely with higher positive vales" should be read as "OvercastDevelopment being increasingly more likely with less negative vales".

OvercastDevelopment Height (BL Condensation Level)

This cloudbase estimate for OvercastDevelopment (extensive clouds and overcast) is the level where the BL humidity equals the dew point temperature based on the BL averaged humidity (mixing ratio) and can be called the "BL Condensation Level (BL CL) based upon BL humidity".

BL Max. Relative Humidity

This parameter gives the maximum relative humidity within the BL and provides an alternative predictor of BL clouds. Larger values indicate a greater probability of deeper and more extensive clouds - but theoretical guidance cannot be given for specific values to be associated with cloud conditions, such as percentages of sky cover by clouds, so this parameter relies completely on empirical calibration for a specific site based upon previous experience,. It is generally recommended that the "Cumulus Potential" or "OvercastDevelopment Potential" parameters be used instead because theoretical criterion values *are* available for them.

CAPE

Convective Available Potential Energy is a measure of the atmospheric stability affecting *deep* convective cloud formation above the BL. Higher values indicates greater potential for strong thunderstorm development and larger updraft velocities. Thunderstorm strengths associated with CAPE values (as published by Wright-Patterson AFB) are: 0=none, 300-1000=weak, 1000-2500=moderate, 2500-5300=strong [note that these values are relative to the very large thunderstorms which occur in the Mid-West!]. This parameter only indicates the *potential* for thunderstorm formation - for thunderstorms to actually form also requires some triggering mechanism which produces upward motion, such as flow over a ridge or convergence. This parameter is obtained directly from model output and not from a BLIPMAP computation.

Surface Dew Point Temperature

The dew point temperature at a height of 2m above ground level, calculated from model outputs of temperature and humidity at 2m AGL.

Fundamental BL parameters:

Boundary Layer Depth

The BL depth is simply the difference between the height of the BL top and the height of the smoothed model topography. This parameter is a fundamental length scale controlling BL behavior.

Surface Heating

The scientific term for this parameter is the "sensible (dry) surface heat flux" where flux here means a movement from the soil into the atmosphere. This parameter is a fundamental one controlling thermals in a convective BL. Of the solar energy absorbed by the earth's surface, some energy warms the soil, some evaporates surface moisture, and some heats the atmosphere; the latter creates surface-based thermal, but energy which goes into evaporation is only useful if the evaporated water again condenses in a cloud to release buoyancy aloft. The rate of surface temperature change depends upon the surface heat flux but also on other factors; near the coast, for example, a strong heat flux can be counteracted by the movement of cold marine air onshore. This parameter is obtained directly from model output and not from a BLIPMAP computation.

Surface Temperature

The temperature at a height of 2m above ground level, obtained directly from model output and not from a BLIPMAP computation.

NAM-model-only Parameters:

Total Cloud Cover

No distinction is made between low, middle, or high level clouds. This parameter is obtained directly from model output and not from a BLIPMAP computation.

Surface Sun

Officially known as the downward short-wave radiation flux at the ground. This parameter is obtained directly from model output and not from a BLIPMAP computation.

Additional Factors:

Neglected Cloud Effects

Convective clouds mark thermals, but they also add buoyancy to the thermals through the release of latent heat of condensation. This should be no surprise to those pilots who have experienced a notable increase in upward motion just below cloudbase, trying to suck the glider into the cloud. BLIPMAP predictions, however, assume that thermals are driven entirely by heating at the earth's surface, so this release of heat aloft is not included in the BLIPMAP buoyancy estimates.

Also, with cloud formation the maximum height to which a glider can climb now becomes limited by the cloud base height, not by the top of the thermal (which is at the top of the cloud!), so the maximum soaring height can no longer be equated to the Hcrit or BL Top BLIPMAP predictions. This dissociation is particularly apparent when maximum lift is found at cloud base - clearly the glider is then not at the top of the thermal!

When convective clouds form, therefore, the *actual* W*, BL Top, Hcrit, and B/S Ratio are all *larger* than the BLIPMAP *prediction* as a result of the additional buoyancy generated aloft in the actual atmosphere. These parameters are increased more by deep cloud convection than by shallow puffy cumulus, since more condensation heating occurs in the former. However, the cloud base is expected to be *below* the maximum thermalling height predicted by the BLIPMAP since the condensation initially occurs in a dry thermal, below the thermal top; again, the deeper the cloud, the larger the difference between the cloud base and the predicted maximum thermalling height.

Because cloud-generated buoyancy is so significant, the best soaring conditions often occur when clouds form - so neglect of this effect is a significant deficiency in the BLIPMAP predictions. Unfortunately, inclusion of cloud-generated buoyancy would be difficult since cloud formation is hard to forecast accurately and since small amounts of condensation can significantly affect thermal strength - trying to include such effects would likely lead to a very noisy parameter that would be very sensitive to errors in the moisture predictions. Because of the omission of cloud-generated buoyancy, it is best to regard the BLIPMAP predictions as forecasts of "minimum" thermalling conditions in the absence of clouds, with cloud formation generally expected to increase updraft velocities and to limit maximum thermalling heights by the cloud base rather than by the thermal top. (Of course the above description applies to convective clouds in their growth stage - at later times the clouds can "overdevelop", forming an overcast which blocks sunlight from reaching the surface, which in turn reduces the surface buoyancy and weakens the thermals.)