Static Stability

(FROM "A REVIEW OF STATIC STABILITY INDICES AND RELATED THERMODYNAMIC PARAMETERS"
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Meteorologists are concerned with static stability parameters in order to understand convective weather patterns. If the atmosphere is unstable with abundant low-level moisture and a mechanism exists to lift the air (thereby releasing the potential instability), convective weather and rainfall (showers) can develop. Conditions favorable for these events are warm, moist air at low levels; cool, dry air aloft; and surface convergence coupled with upper-level divergence. A study done by Wilson and Scoggins (1976) report that convective activities exist "in areas where the low and middle troposphere is moist, air is potentially and convectively unstable, and has upward motion, in combination with positive moisture advection, at either the surface or within the boundary layer."

Static stability is defined as the stability of the atmosphere in hydrostatic equilibrium with respect to vertical displacements. These displacements are explained by using the parcel method. The parcel is a hypothetical box that does not allow any transfer of heat into or out of the box, but allows only adiabatic temperature changes. The stability of the parcel is dependent upon the parcel's motion after a forced displacement from an original location. As the parcel undergoes adiabatic change, its temperature is compared to that of the surrounding environment so as to relate differences in density. A parcel that returns to its original position is considered stable while one that will continue away from its original position is unstable. One that is displaced and remains at its new position is considered neutral.

Since the density differences are affected by the differences between the adiabatic lapse rates and the environmental lapse rate, one may denote **absolute instability** occurring when the environmental lapse rate, Γ_E, exceeds the dry adiabatic lapse rate, Γ_D; **absolute stability** occurring when Γ_E is less than the wet adiabatic lapse rate, Γ_W; and **conditional instability** when Γ_E falls between Γ_W and Γ_D. The atmosphere may be considered **potentially unstable,** (or synonymously **convectively unstable)** when referring to the atmosphere's *potential* for releasing instability, even when the atmosphere appears to be stable. A layer may be strongly stable (that is, it has a negative lapse rate) and yet still considered to be potentially unstable. This is favored when the bottom of a specific layer is warm and moist while the top of the layer is substantially drier.

The layer method of determining stability involves *dynamically* lifting a layer of the atmosphere by low-level convergence, an approaching front, etc., similar to the parcel. The restriction of horizontal mixing is eliminated. However, the vertical pressure difference between the top and bottom of the layer must remain constant. As the layer is lifted, the bottom of the layer will saturate more quickly than the top, hence cooling slower than the drier top. This lifting will result in a *destabilization* of the atmosphere. (See Figure 1.) The original layer is considered convectively unstable if at the point of total saturation, the layer has a lapse rate greater than the Γ_w. This criterion can be represented by determining the change of the equivalent potential temperature with height. If $\frac{d\theta_e}{dZ} < 0$, the atmosphere is considered convectively unstable.

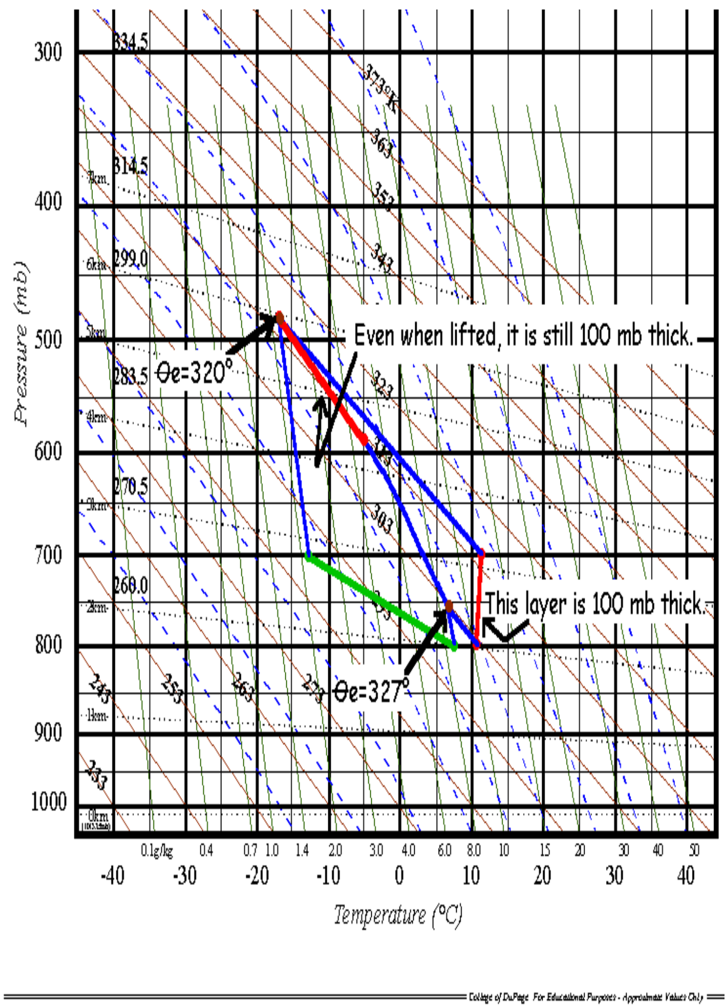

Figure 1

Notice that the layer started out absolutely stable (a slight inversion) As the top cooled dry adiabatically and the bottom cooled slower, the layer destabilized. If θ_e at the bottom is greater than θ_e at the top, as it is in this case, then the layer's lapse rate is greater than the local wet adiabatic lapse rate and the layer is convectively unstable.

Stability Indices

LIFTED INDEX $LI = T_{500} - Tp_{500}$;

where the mean mixing ratio of the lowest 3000' and the potential temperature of the predicted afternoon high are used. This is known as a "mixed" parcel. It uses what the expected (or *prognosticated*) atmosphere will be. The LI can be used as a *diagnostic* tool as well if the current surface temperature is used. The lower the value (i.e. the greater the negative number), the better the chance for thunderstorms and the greater the threat for severe weather.

SHOWALTER INDEX $SI = T_{500} - Tp_{500}$;

where Tp_{500} is the temperature of a parcel lifted dry adiabatically *from 850 mb* to its condensation level and moist adiabatically to 500 mb.

SI values ≤ +3 indicate possible showers or thunderstorms.

SI values ≤ -3 indicate possible severe convective activity.

Notice, the formula for the SI and the LI are the same, but the value of Tp_{500} depends on where the parcel started. The Lifted Index lifts a parcel from the surface (even if it is a mixed-parcel) while the Showalter Index starts a parcel at 850mb.

K-INDEX $K = (T_{850} - T_{500}) + Td_{850} - (T_{700} - Td_{700})$

The K index is a poor indicator of severe thunderstorms since dry air at 700 mb may indicate convective instability. Dry air at 700 mb will give a low value to the K-Index.

K values ≥+20 indicate some potential for air mass thunderstorms.

K values ≥ +40 indicate almost 100% chance for air mass thunderstorms,
with values over +30 to indicate potential MCC's.

TOTAL TOTALS INDEX $TT = T_{850} + Td_{850} - 2T_{500}$

TT values ≥ +60 indicate probable moderate thunderstorms,
with a possibility of scattered severe t-storms.

The total totals index is actually a combination of the vertical totals, VT = T_{850} - T_{500}, and the cross totals, CT = Td_{850} - T_{500}, so that the sum of the two products is the total totals.

SWEAT INDEX (SEVERE WEATHER THREAT)

$$SWEAT = 12Td_{850} + 20(TT - 49) + 2f_{850} + f_{500} + 125(s + 0.2);$$

where the first term is set to zero if the 850 mb Td (°C) is negative; TT is the Total Totals Index (if TT < 49, the term is set to zero); f is the wind speed in knots; and s = sin (500 mb wind direction - 850 mb wind direction). The last term is set to zero if any of the following is <u>not</u> met:

1) the 850 mb wind is between 130°-250°;
2) the 500 mb wind is between 210°-310°;
3) (the 500 mb wind direction - the 850 mb wind direction) is greater than zero; or
4) both the wind speeds are greater than or equal to 15 kts.

SWEAT values ≥ +250 indicate a potential for strong convection.
SWEAT values ≥ +300 indicate the threshold for severe thunderstorms.
SWEAT values ≥ +400 indicate the threshold for tornadoes.

Keep in mind that these indices are **empirical** only, that is, they are not governed by any physical laws. They are used by meteorologists to give a quick estimate of the atmosphere's condition. Whether the indices are high or low, a good forecaster needs to answer the question "What is the condition that this index is measuring?" Remember, thunderstorms need lift moisture and instability. These indices are nothing more than estimated tools for identifying some of these ingredients.