Atmospheric Stability
A Primer for Pilots

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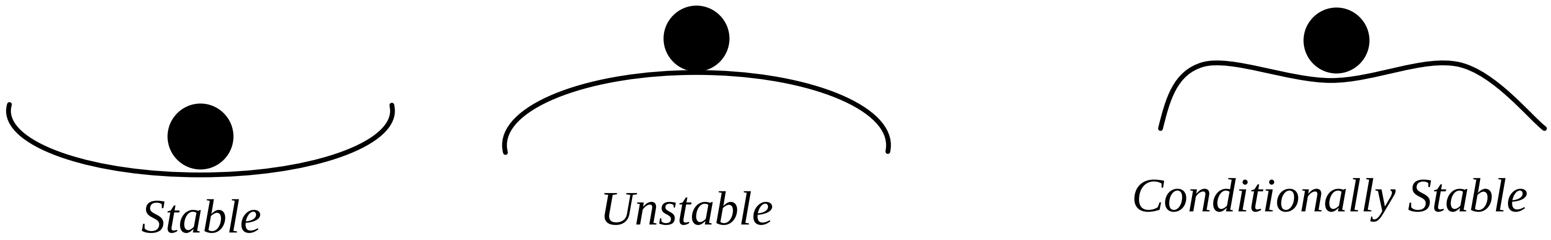
http://williams.best.vwh.net/

A little weather "theory" is good for you!

- To realize *what* is happening, it helps to know *why*.
- We mostly likely don't have the skill and knowledge of a professional meteorologist. But we do have the advantage of being on the spot, in real time.
- "(In)Stability" is a fundamental underlying concept in the analysis of weather phenomena.

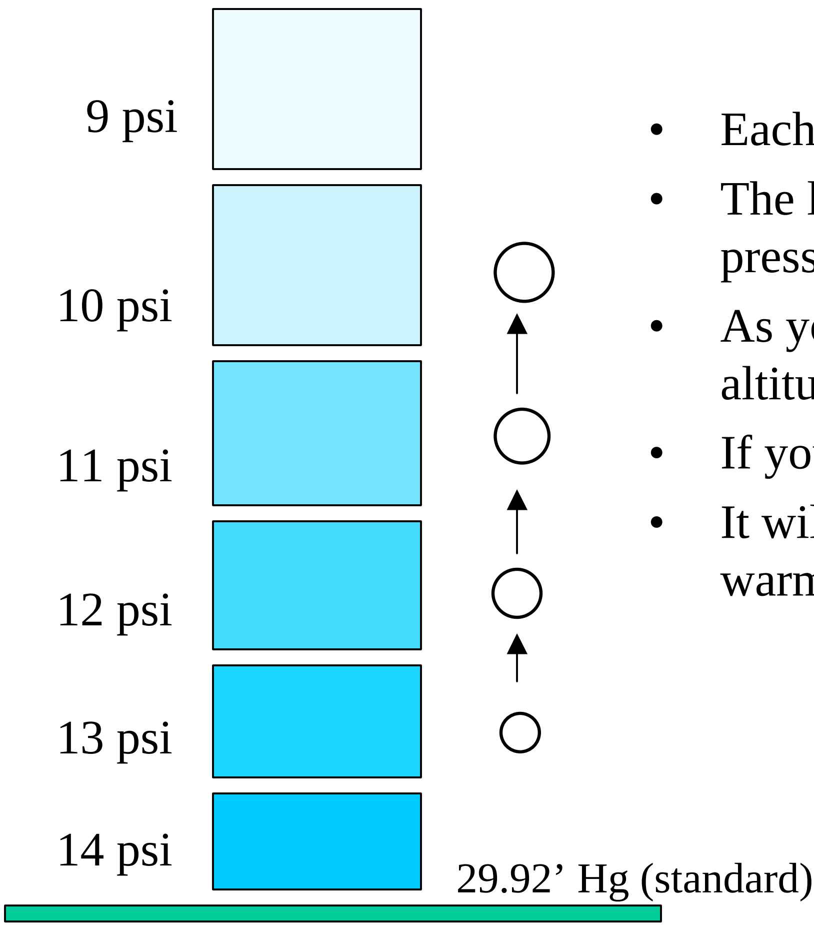
Stable systems return towards equilibrium when displaced



? A region of the atmosphere is stable if on lifting a parcel of air, its immediate tendency is to sink back when released.

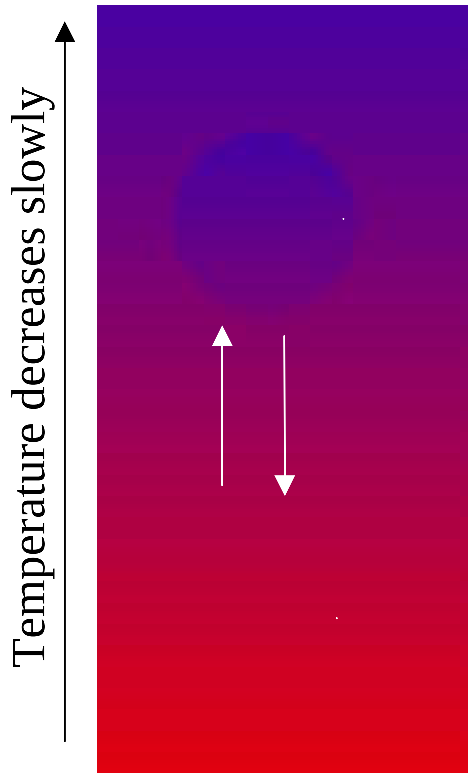
? This requires the displaced air to be colder (and thus denser) than its surroundings.

Pressure is the weight per unit area of the air above.

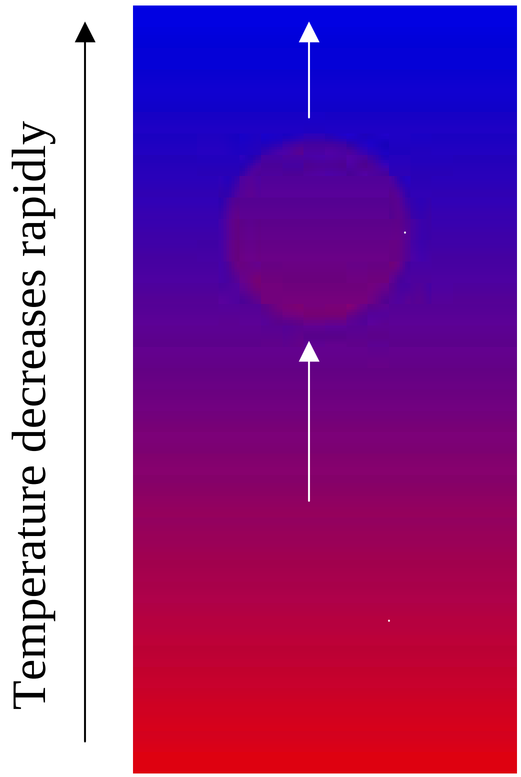


- Each layer supports all the layers above.
- The lower layers are compressed more by the greater pressure.
- As you climb, the pressure drops more slowly with altitude.
- If you lift a parcel of air it will expand and cool.
- It will continue to rise, if despite this cooling, it is warmer than its surroundings.

The atmosphere becomes unstable if the temperature drops sufficiently rapidly with altitude



Stable air



Unstable air

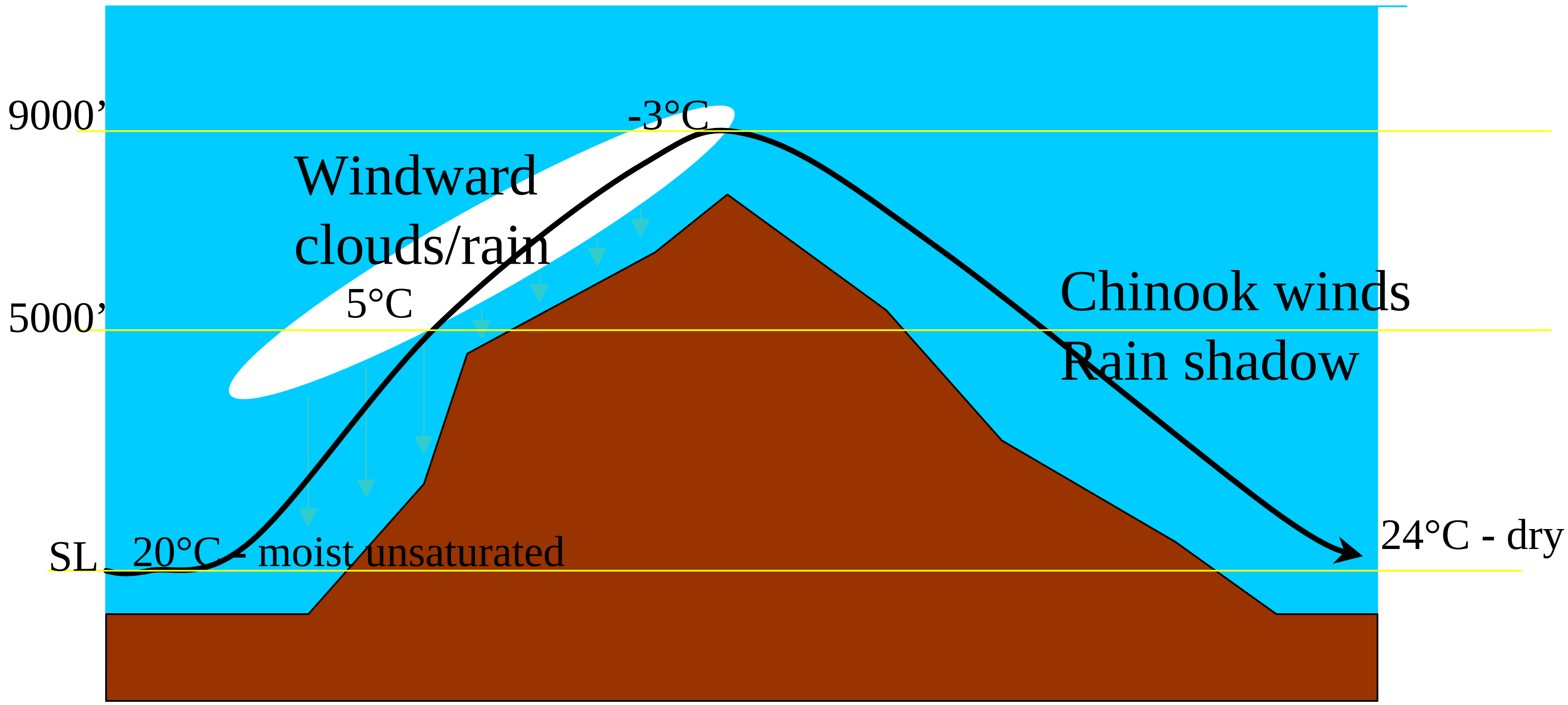
Lifted air expands and cools at the *adiabatic* lapse rate

"Adiabatic" means no heat is absorbed from or given to the environment

Dry (=unsaturated) air cools at a constant 3C/1000ft.
This is reversible.

When saturated air (RH=100%) expands and cools, moisture condenses and latent heat is released - offsetting some of the cooling. The *moist (saturated) adiabatic lapse rate* varies with temperature: 1C/1000ft at high temperatures to 3C/1000ft well below freezing - depending on the absolute moisture content.
This is typically not reversible. The condensed moisture precipitates out and is not available to be absorbed if the parcel descends and compresses.

Santa Ana/Chinook/Foehn conditions arise from this irreversibility



The saturated air on the windward side cools more slowly as it rises than the dried air warms on its leeward descent.

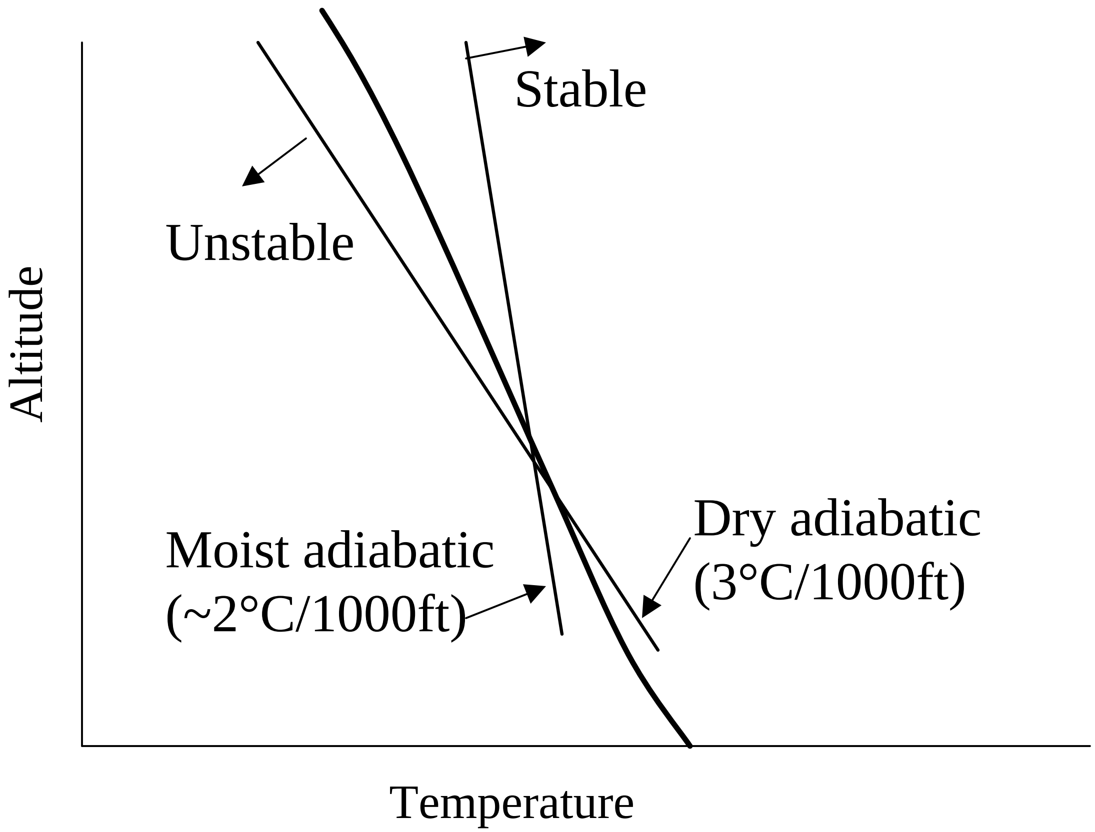
Other lapse rates...

? A *lapse rate* is the rate of decrease of some temperature with altitude.

? The *standard* lapse rate of 2°C/1000ft: performance/reference.

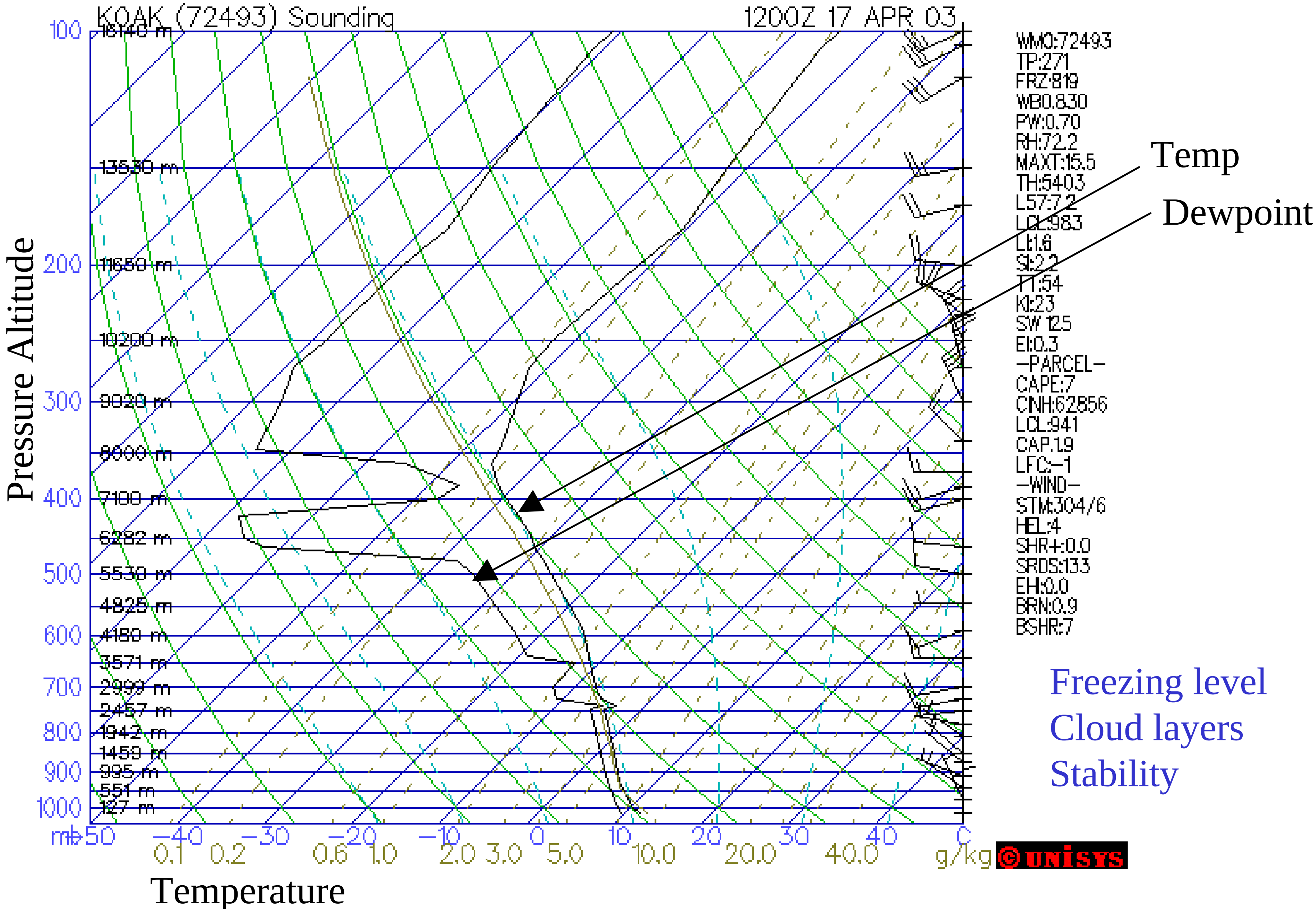
? The *ambient* lapse rate is as present - eg as measured by a radiosonde balloon.

Instability results if the ambient lapse rate exceeds the adiabatic lapse rate



Conditional instability when the ambient lapse rate lies between the dry and moist rates. The air is then unstable if it is/becomes saturated.

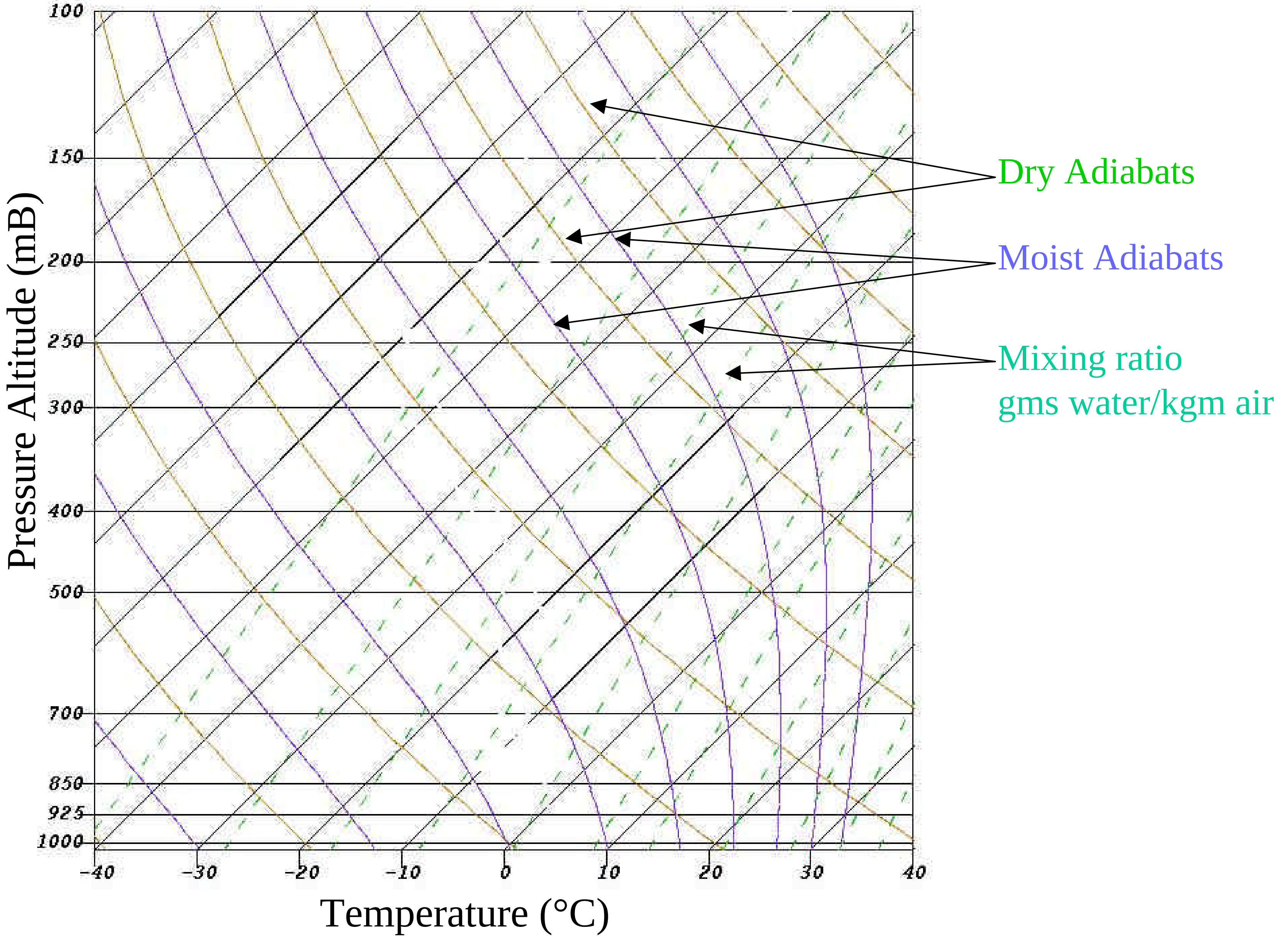
RAOB data is plotted on “Skew-T” charts - Worldwide 00Z/12Z daily



Freezing level
Cloud layers
Stability

http://weather.unisys.com/upper_air/skew/

Skew-T plots are an indispensible tool for meteorologists - but require a lot of training in their use...

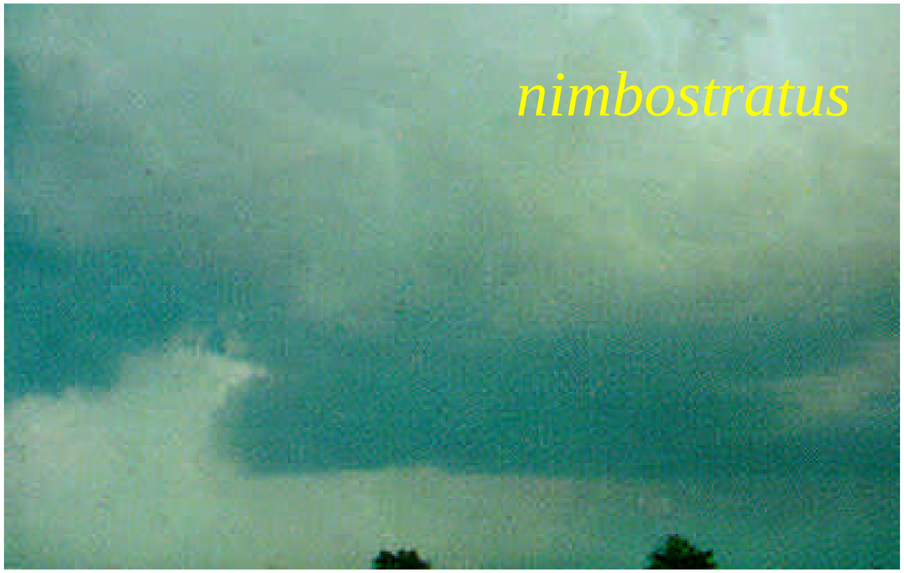


Characteristics of (un)stable weather

Weather condition	Stable	Unstable
Turbulence	Smooth	Bumpy, UDDF
Clouds	Stratus,layered	Cumulus, heaped
Precipitation	Steady	Showery
Visibility	Poor	Good
Surface Winds	Steady	Gusty
Icing	Rime, continuous	Clear/mixed, intermittent

- Key is that unstable convects and mixes the air vertically.

Stratus type clouds form in stable air.



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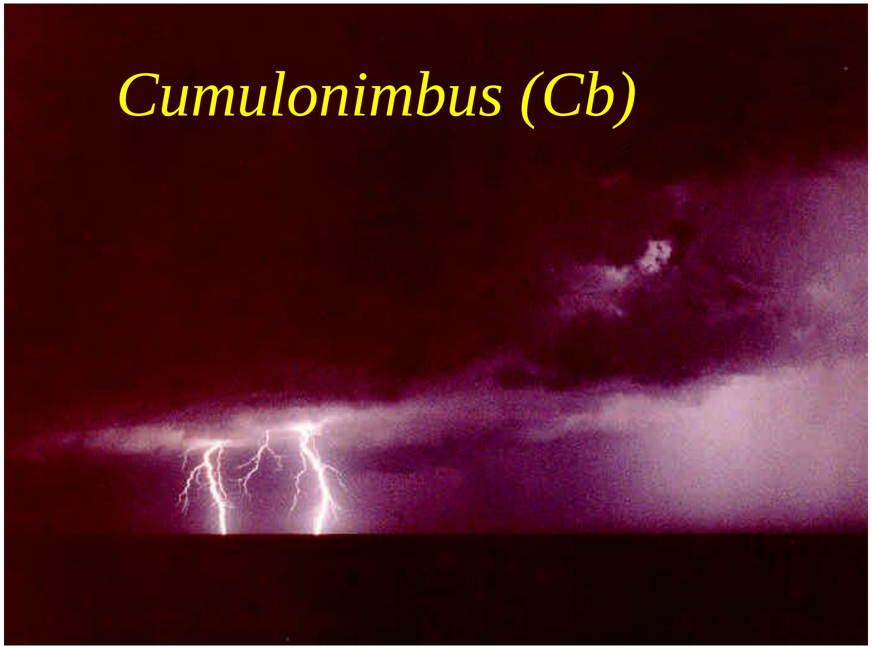
Cumulus type clouds form in unstable air



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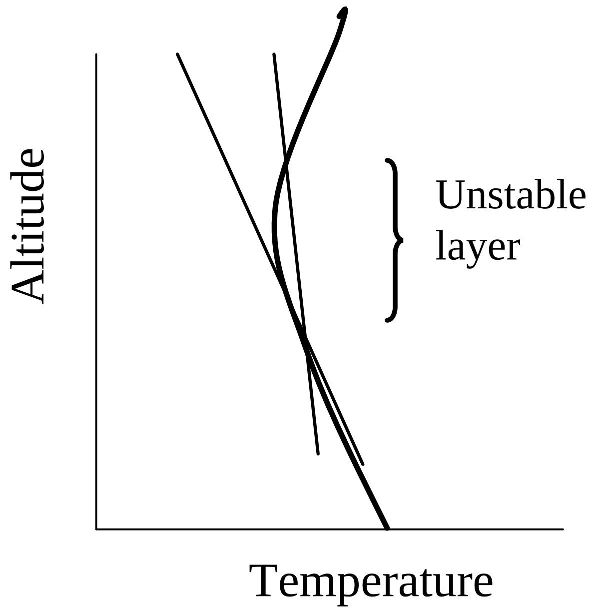
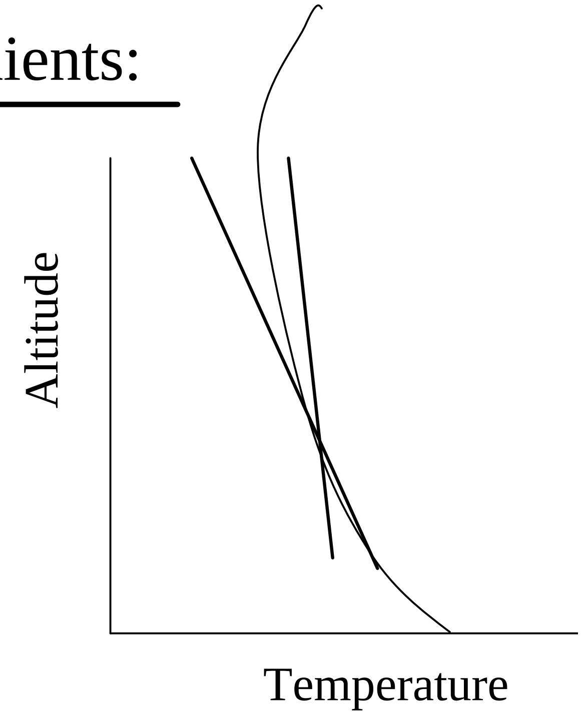
Shallow layers of (conditionally) unstable air promote “fair weather cumulus”



Instability triggered by surface heating or lifting.

Cloud bases at the “lifting condensation level” (surface temp - dewpoint °F)/4.4 in 1000’s feet.

Thunderstorms development requires three ingredients:



- A deep layer of (conditionally) unstable air.
  Cu can build into Cb

- High moisture content
  The latent heat of condensation provides the megatons of energy.

- Lifting action
  Airmass
  Frontal
  Squall line
  Orographic

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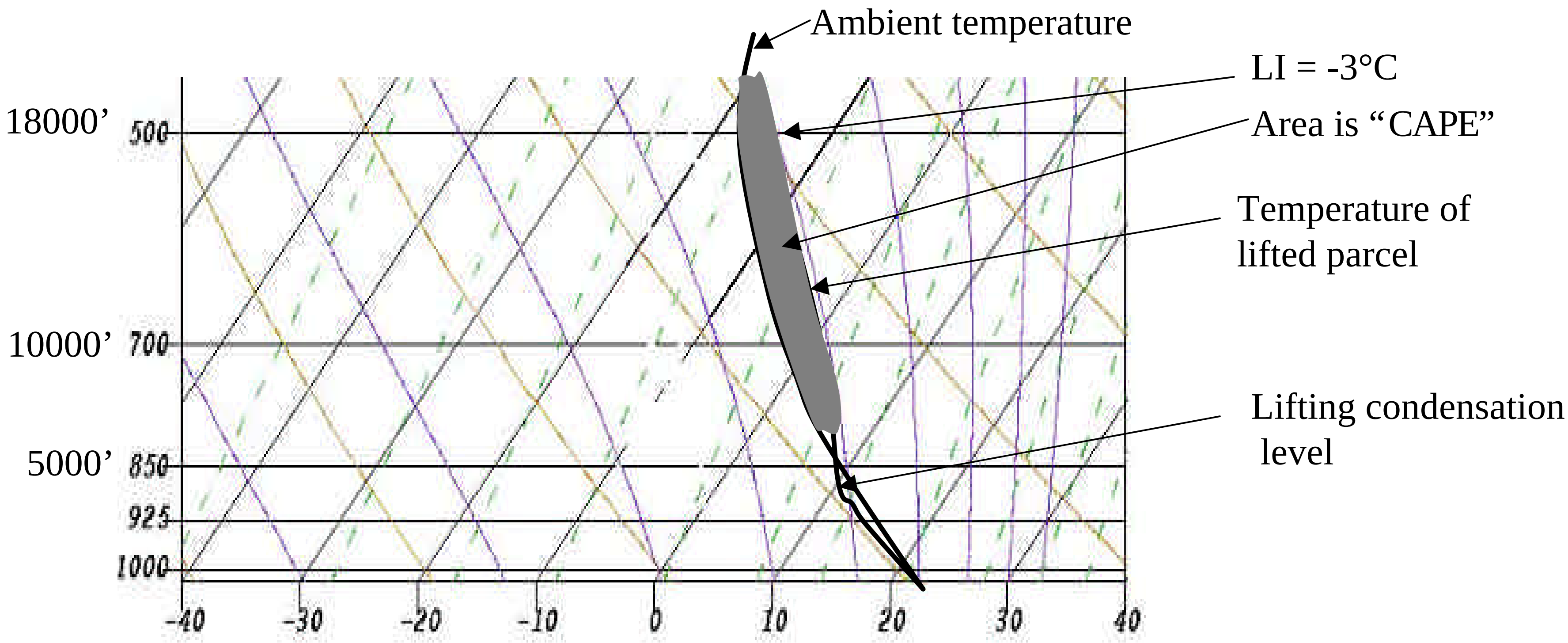
Stability/low level moisture is forecast on Lifted Index/K-Index charts



Lifted Index = Temp at 500mB - Temp of a parcel adiabatically to 500 mB

LI < 0 => potential instability

K-Index = Temp at 850mB -Temp at 500mB

+ Dewpoint at 850 mB

- (Temp at 700mB - Dewpoint at 700mB)

Larger K-index = more low level moisture

The lifted (LI) and K (KI) indices are measures of stability and low level moisture

LI>0 KI<20:	dry, stable:	predominantly fair, smooth
LI>0 KI>20:	wet, stable:	stratus, rain, smooth
LI<0 KI<20:	dry, unstable:	fair wx Cu, bumpy
LI<0 KI>20:	wet, unstable:	TRWs, bumpy

Table 9-1 Thunderstorm Potential

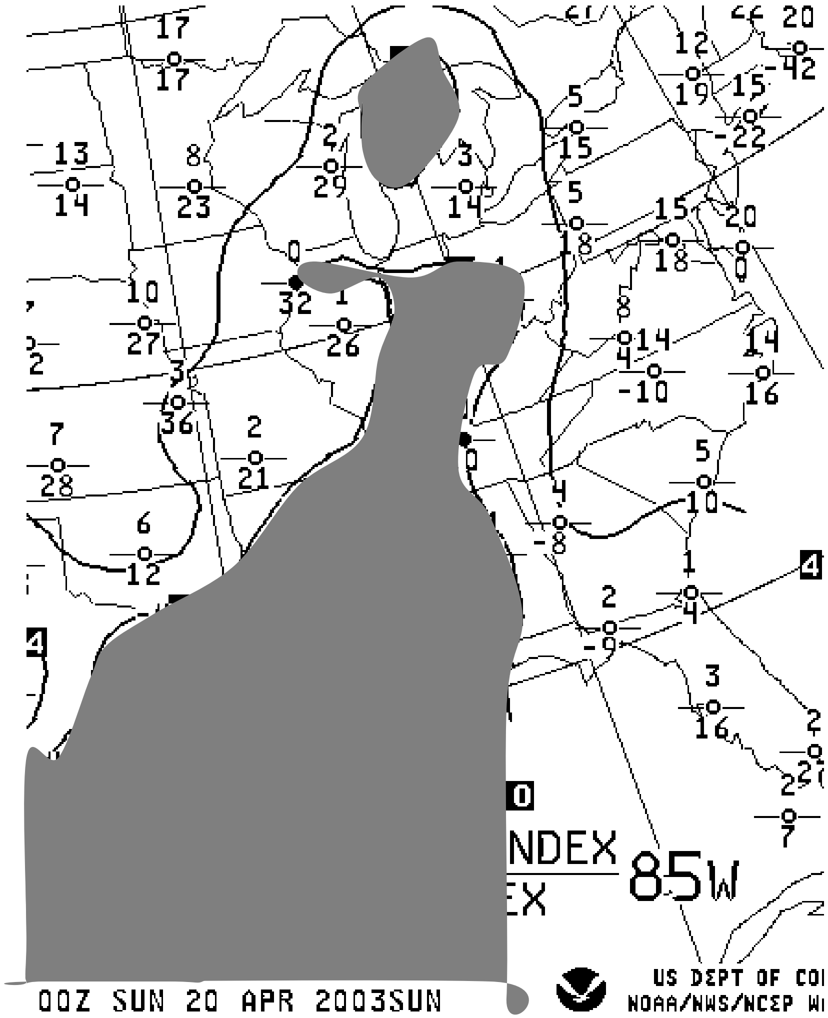
Lifted Index (LI)	Severe Potential
0 to -2	Weak
-2 to -6	Moderate
≤-6	Strong

K Index (KI)	Thunderstorm Probability
< 15	near 0%
15-19	20%
20-25	21%-40%
26-30	41%-60%
31-35	61%-80%
36-40	81%-90%
> 40	near 100%

AC 00-45A Aviation Wx Services - section 9

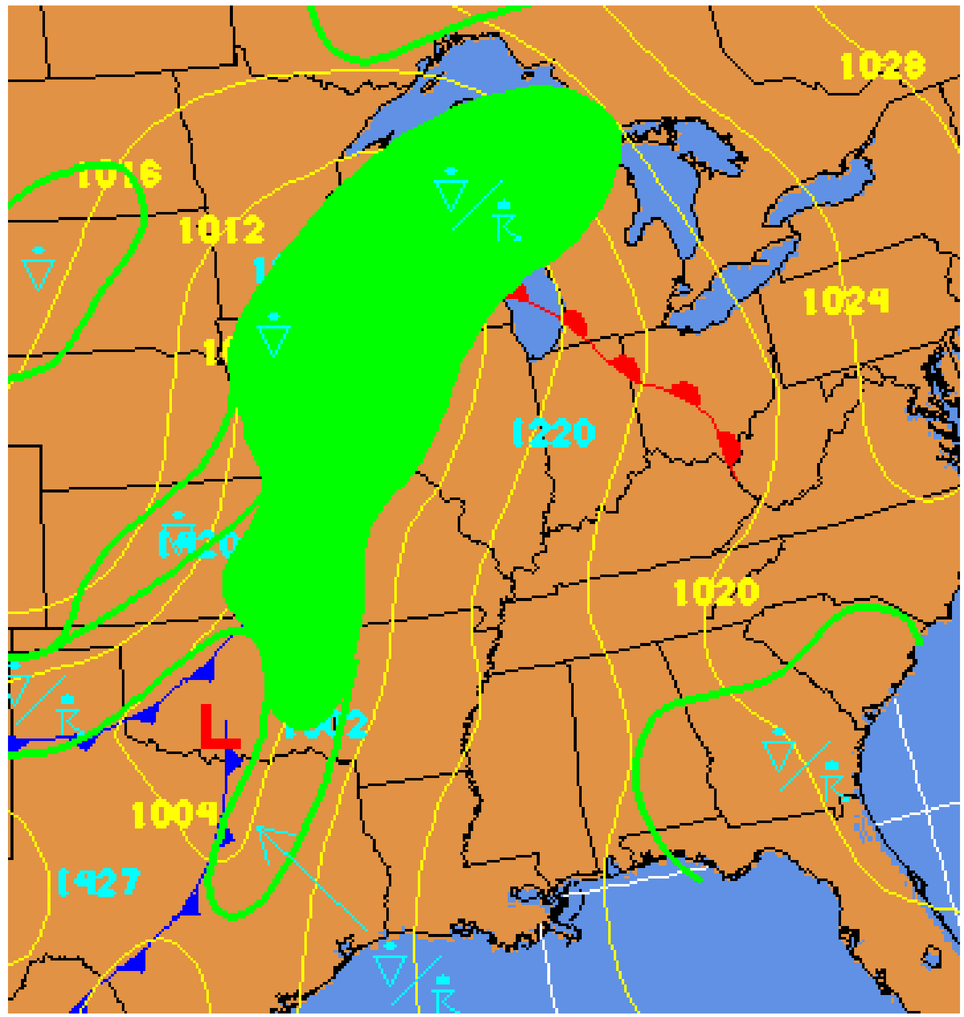
Negative Lifted Indices and TRWs are forecast between the Texas Gulf Coast and the Great Lakes

Lifted Index/K-index prog chart



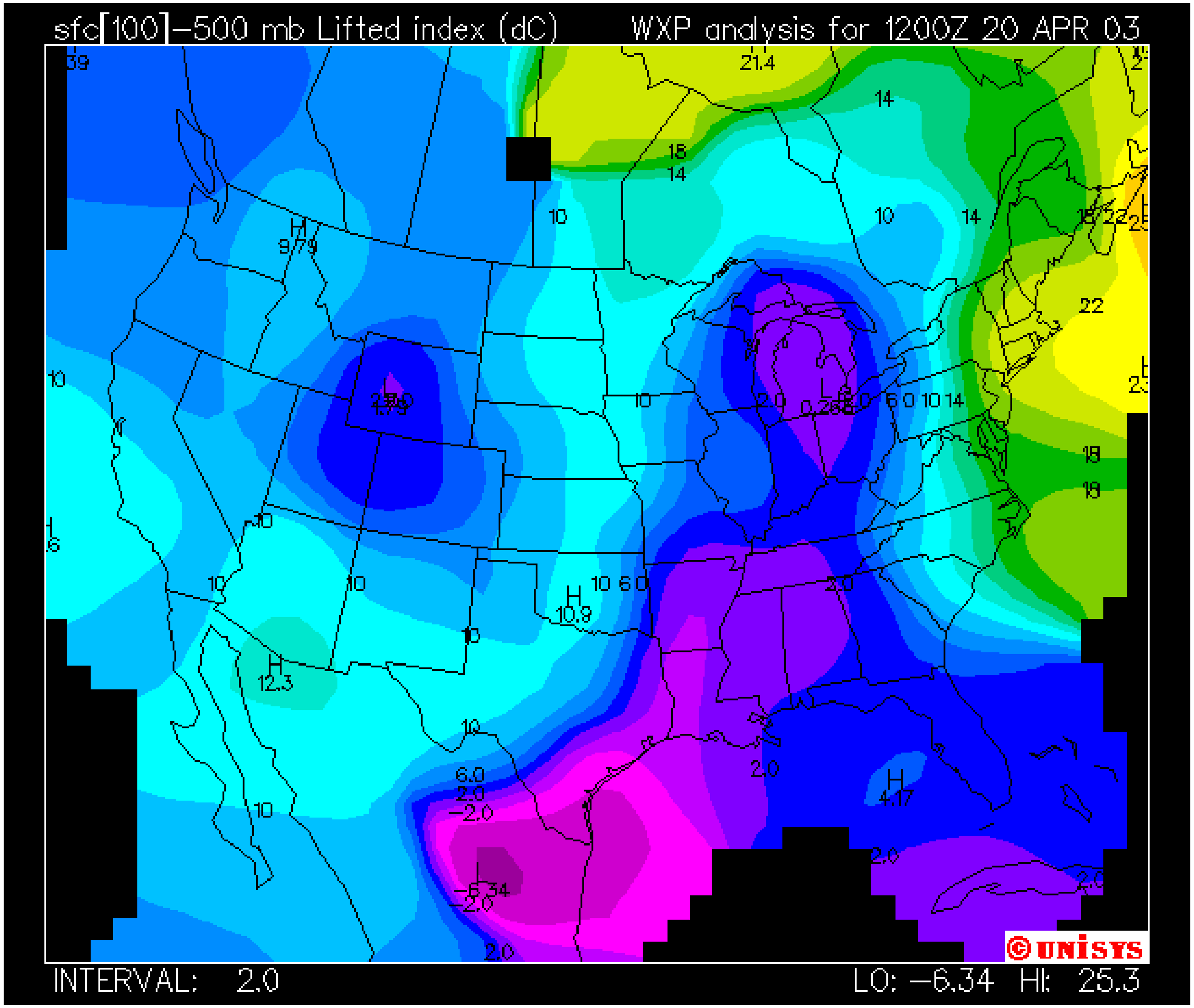
http://weather.noaa.gov/fax/panel2.shtml

Low level sig wx surface prog chart



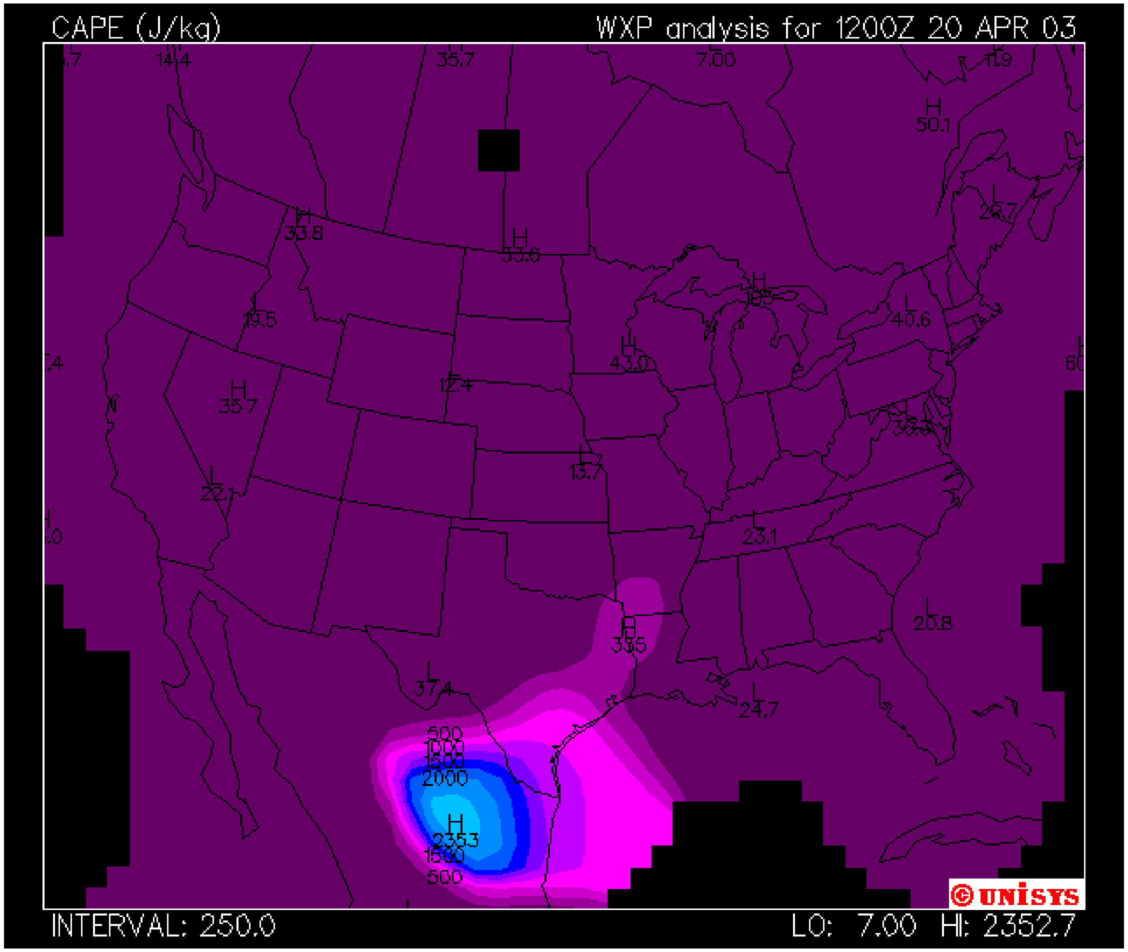
http://aviationweather.gov/awc/lolvl.html

Lifted Index from the UNISYS site.



http://weather.unisys.com/upper_air/ua_con_lift.gif

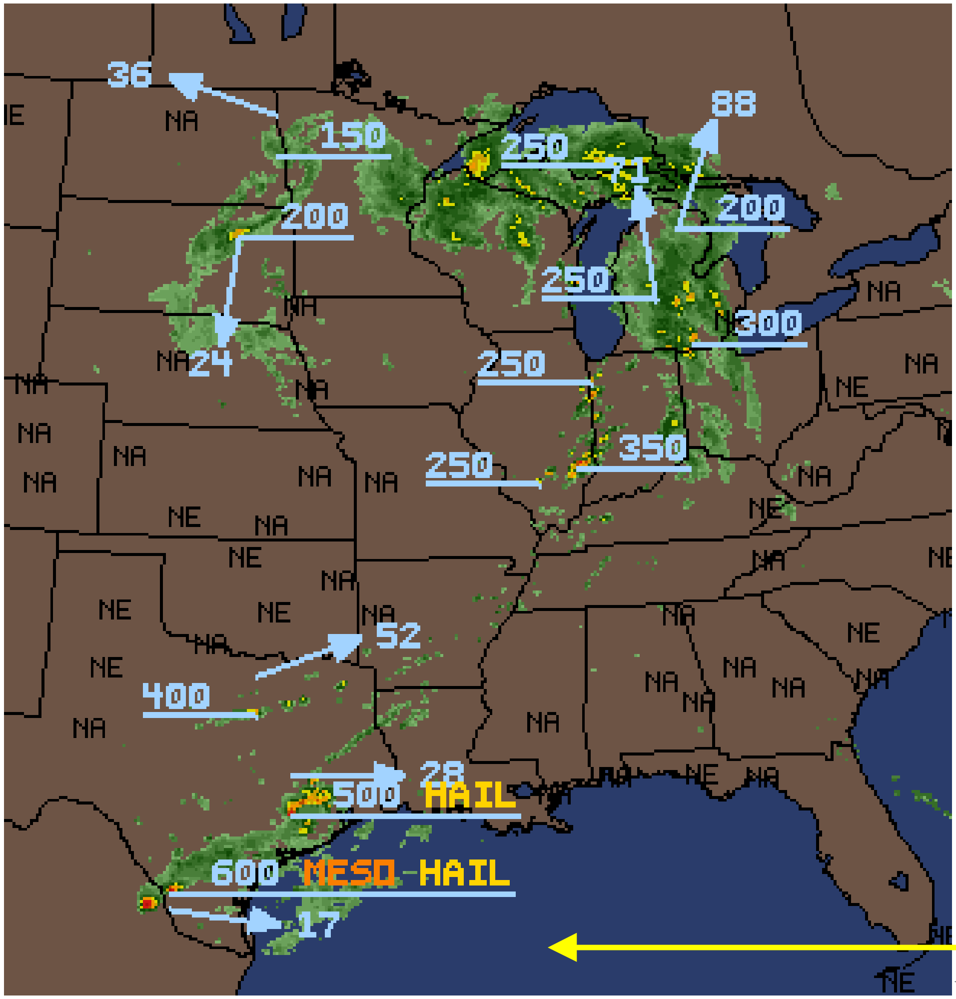
CAPE is another useful diagnostic for TRW potential.



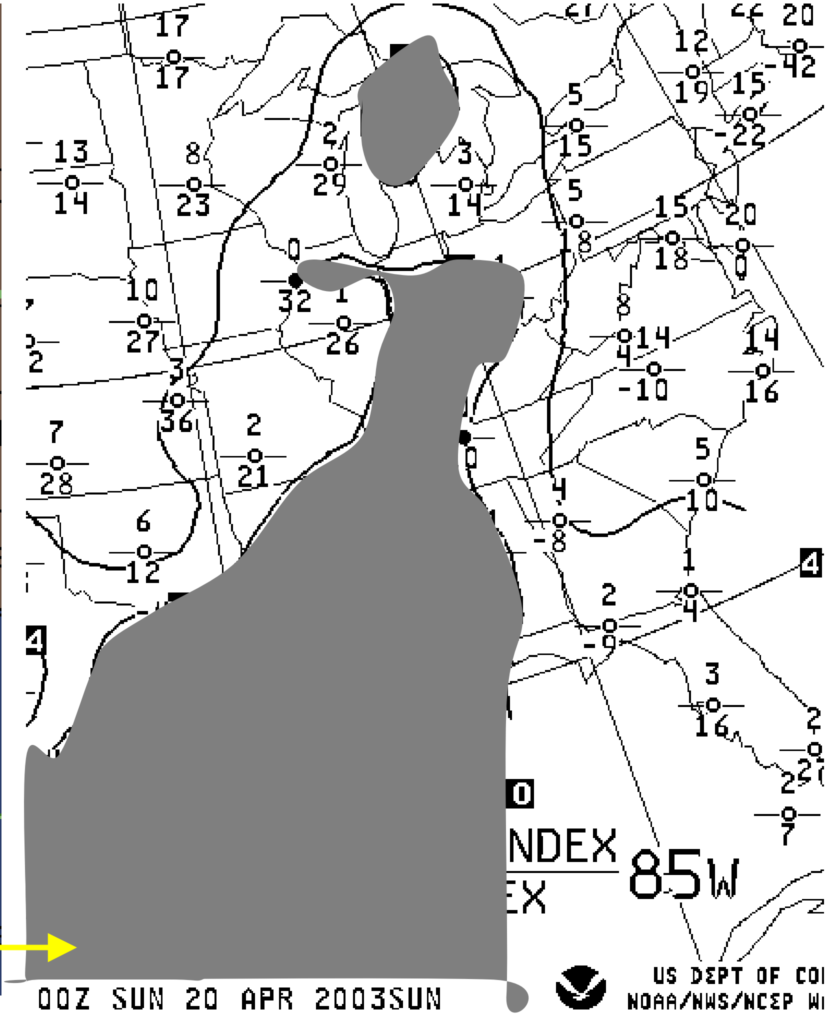
This is a contour plot of CAPE or Convective Available Potential Energy. CAPE represents the amount of energy a parcel might have if it were lifted. Often this reflects the strength of updrafts within a thunderstorm. CAPE values of greater than 2000 represent enough energy to produce thunderstorms. A value greater than 3000 represents enough energy to produce strong thunderstorms. Values < 1000 denote a reletively stable atmosphere.

The forecast was borne out by later TRW development.

- *Note that the highly unstable air on the Texas Gulf coast produced 50-60,000 ft TRWs!*



US Radar Summary http://www.intellicast.com

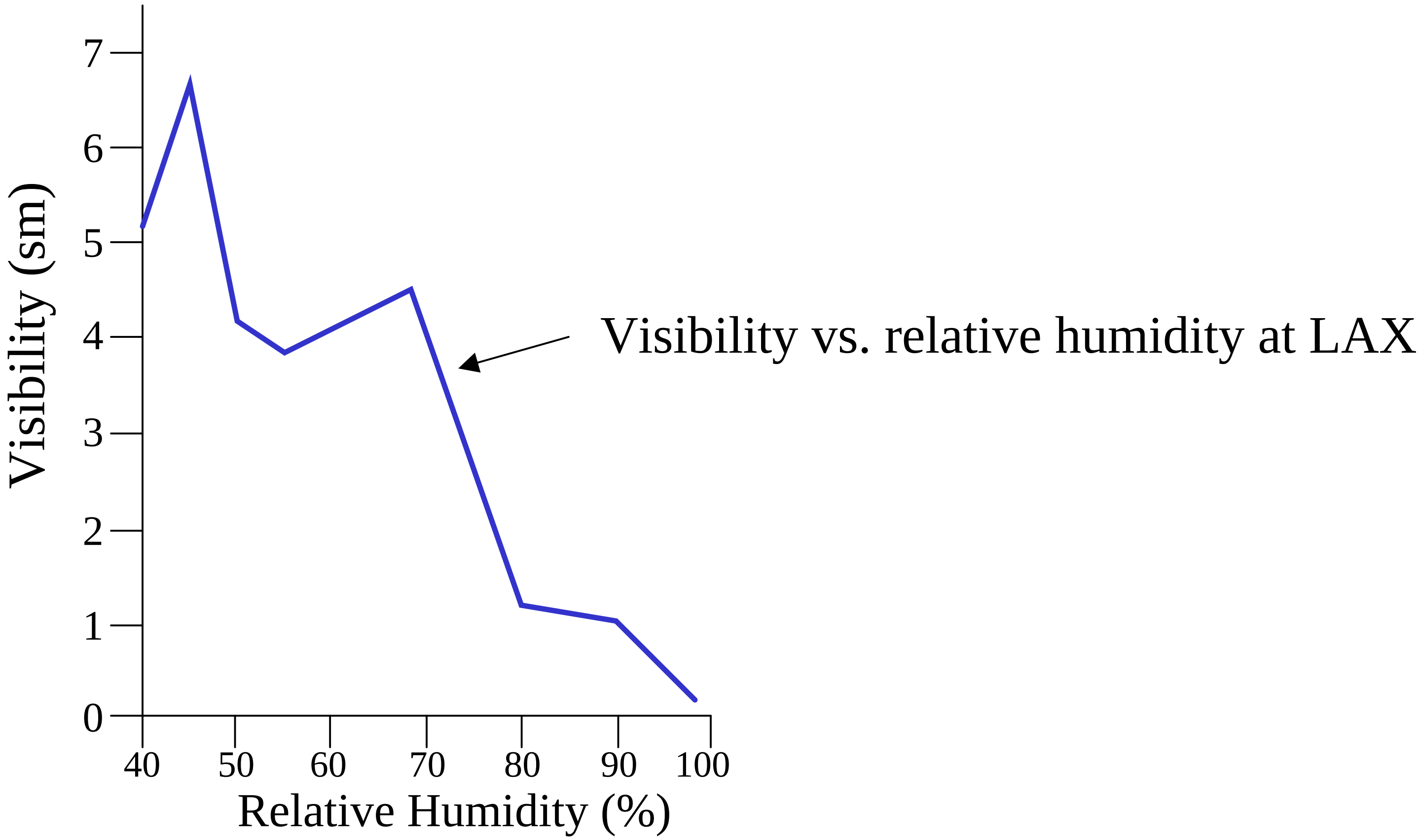


Lifted Index/K-index prog chart

“Stable” doesn’t necessarily mean “good”!

• Stratus clouds and fog if air is saturated.

• In dirty air, visibilities drop before temperature and dewpoint meet.



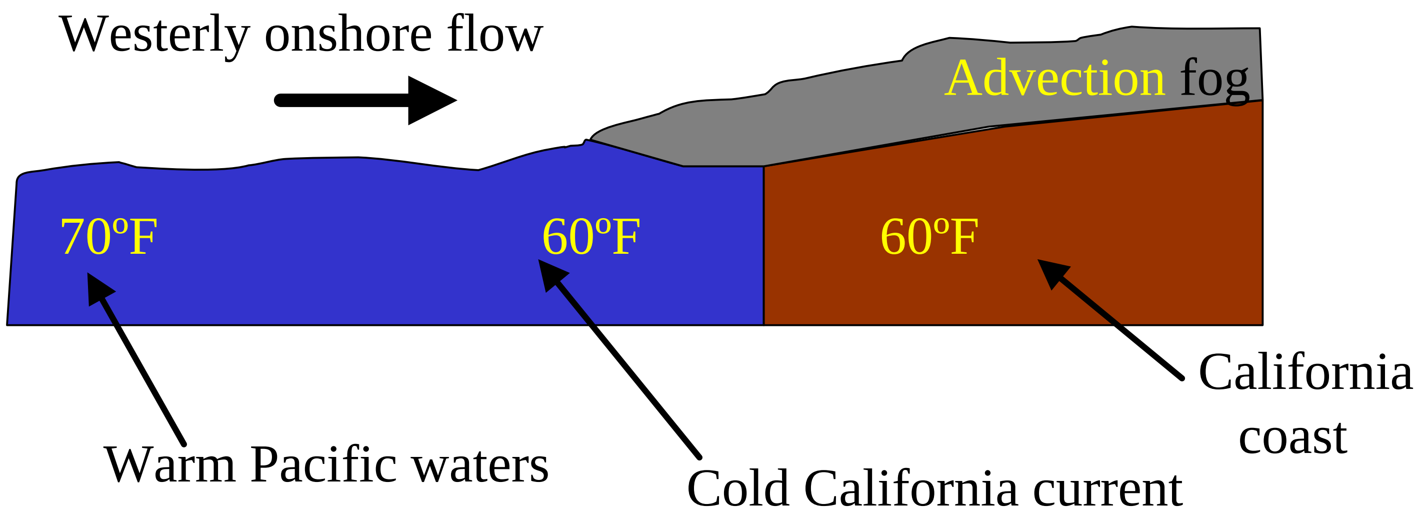
To create fog - a cloud at the surface, the temperature and dewpoint must close.

Type	Mechanism	Stability?	Factors
Radiation	Cooling	S	Clr skies, light wind, land
Advection	Cooling	S	Colder land/water surface, wind
Upslope	Lifting	S	Upslope wind
Precip.	+ Moisture	S	Warm front
Steam	+ Moisture	U	Warm water

Radiation or *ground* fog occurs when the ground cools by radiation.

- ✍ Forms at night under clear skies, but high humidity.
- ✍ Radiation fog is restricted to land because water surfaces cool little from nighttime radiation.
- ✍ It is shallow when wind is calm.
- ✍ Winds up to about 5 knots mix the air slightly and tend to deepen the fog by spreading the cooling through a deeper layer. Stronger winds disperse the fog or mix the air through a still deeper layer with stratus clouds forming at the top of the mixing layer.

Advection of warm moist air over a cold surface is a fog maker.



Warm moist air off the Pacific is cooled to its dewpoint by the cold California current and then advected inland.

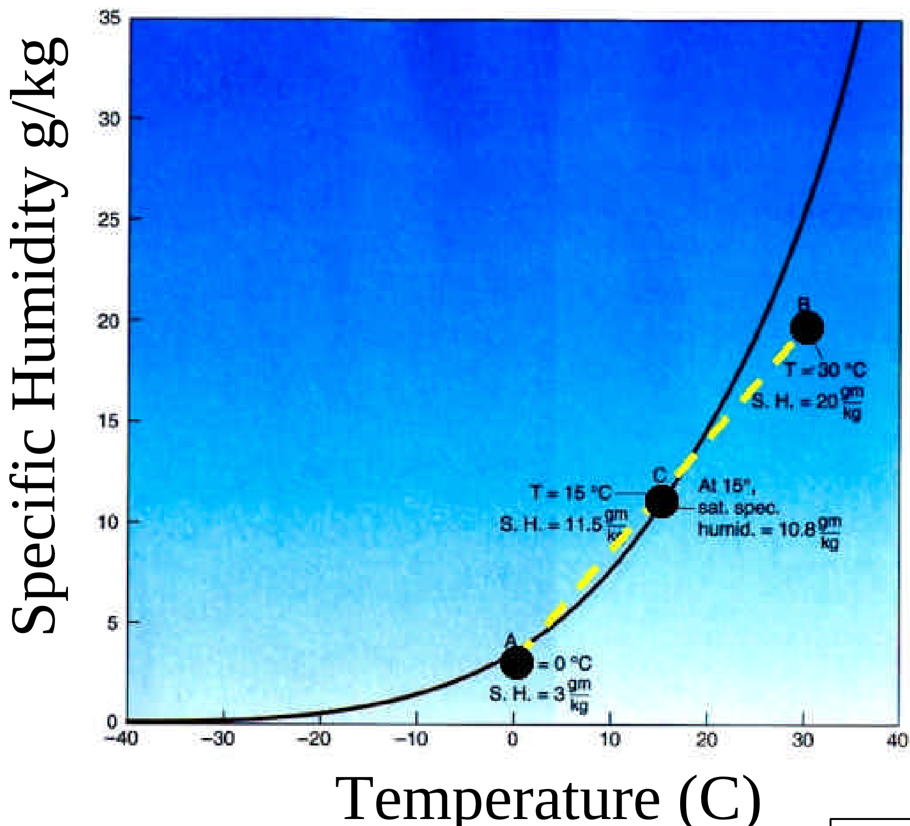
On the East coast, in winter, warm moist air from the Atlantic is cooled by the land.

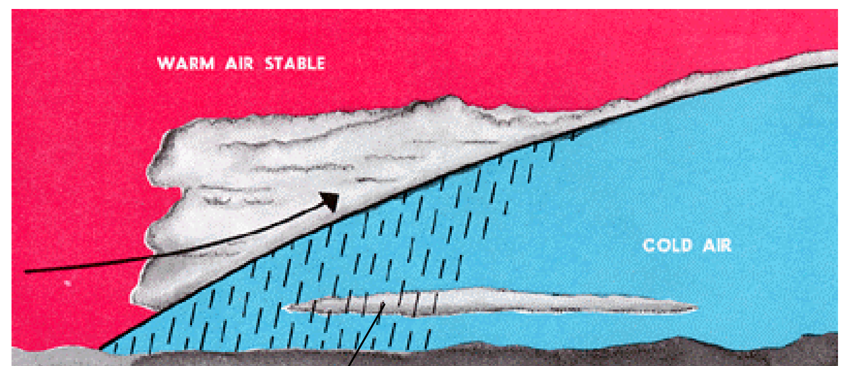
Prevailing winds driving moist air up rising terrain can give widespread *upslope* fog.

SE winds off the gulf of Mexico give rise to *upslope* conditions along the front range
of the Rocky Mountains.

Moist air adiabatically cools below its dewpoint as it is lifted.

Mixing cold and warm moist (but unsaturated!) air can make clouds.





Precip-induced fog and stratus