Isentropic Analysis Techniques: Basic Concepts

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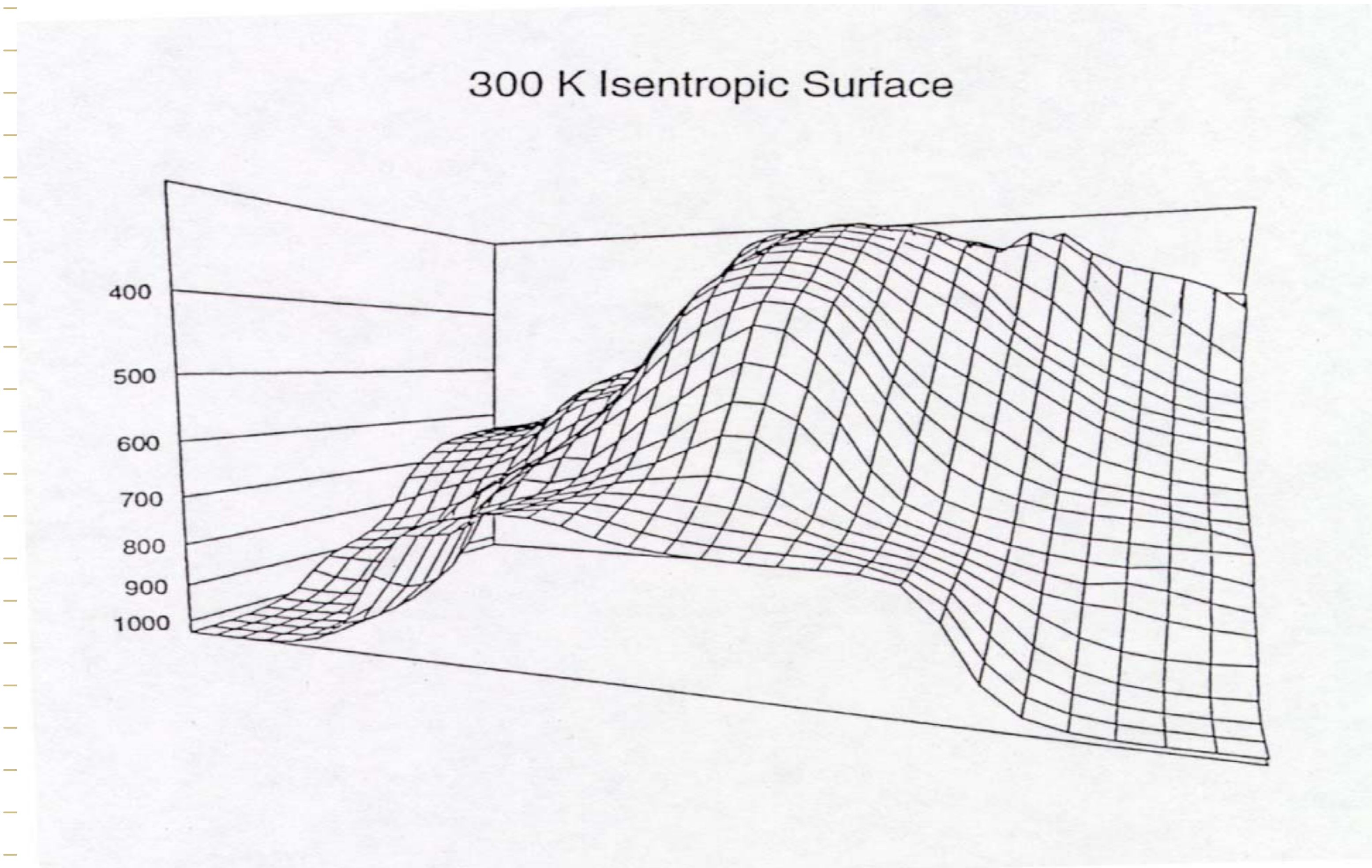
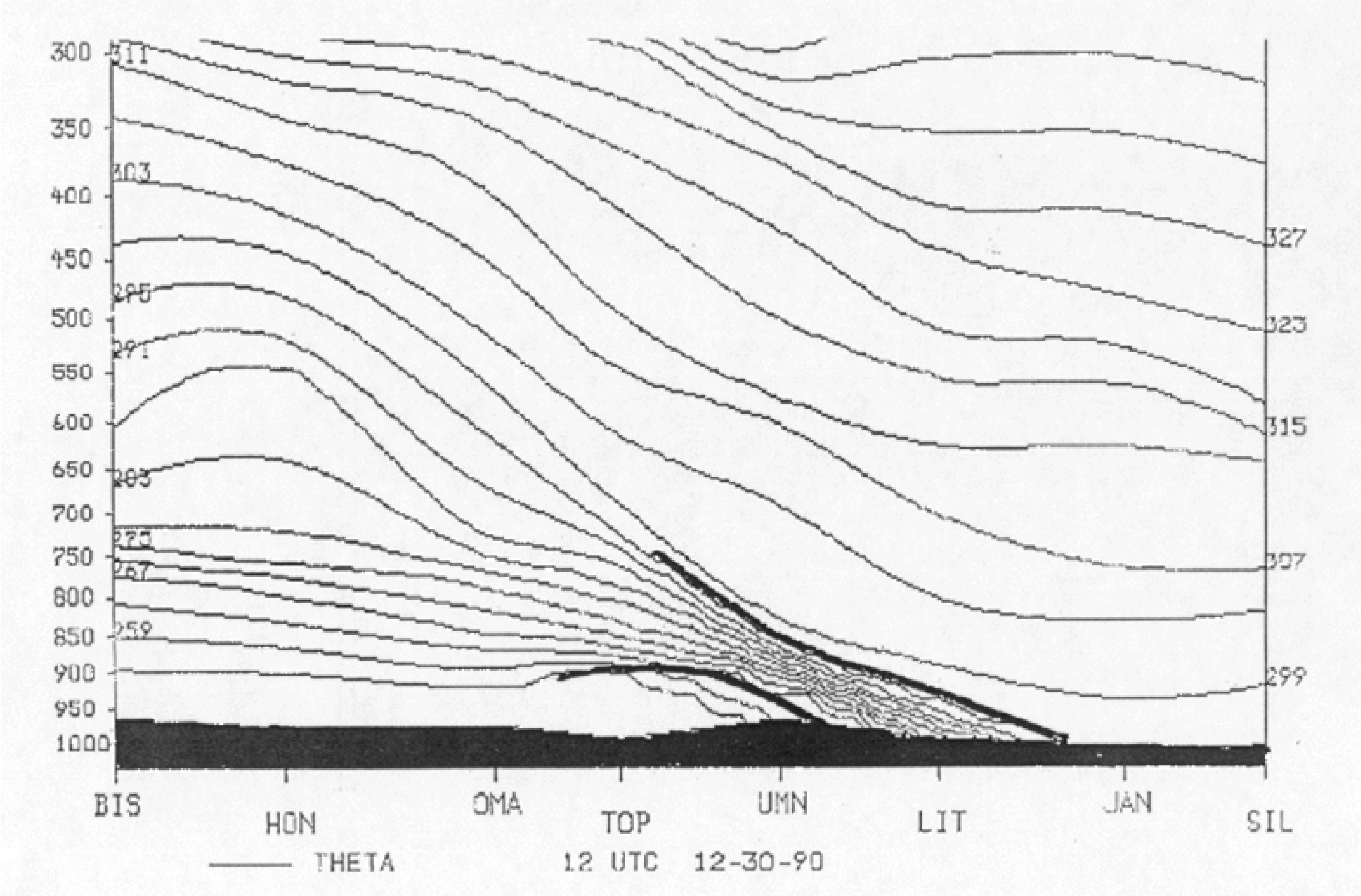
Theta as a Vertical Coordinate

- $\theta = T\,(1000/P)^{\kappa}$, where $\kappa = R_d / C_p$
- Entropy = $\phi = C_p \ln\theta$ + const
- If ϕ = const then θ = const, so const entropy sfc = isentropic sfc
- Three types of stability, since $\delta\theta/\delta z = (\theta/T)\,[\Gamma_d - \gamma]$
  - stable: $\gamma < \Gamma_d$, θ increases with height
  - neutral: $\gamma = \Gamma_d$, θ is constant with height
  - unstable: $\gamma > \Gamma_d$, θ decreases with height
- Isentropes slope DOWN toward warm air, up toward cold air.
- On an isentropic surface an isotherm = an isobar = an isopycnic (const density)
- On an isentropic surface we analyze the Montgomery streamfunction to depict geostrophic flow, where:
  - $M = \psi = C_p T + gZ$

Three-Dimensional Isentropic Topography



Cross Section Taken Normal to Arctic Frontal Zone: 12 UTC 30 December 1990



Vertical Resolution is a Function of Static Stability

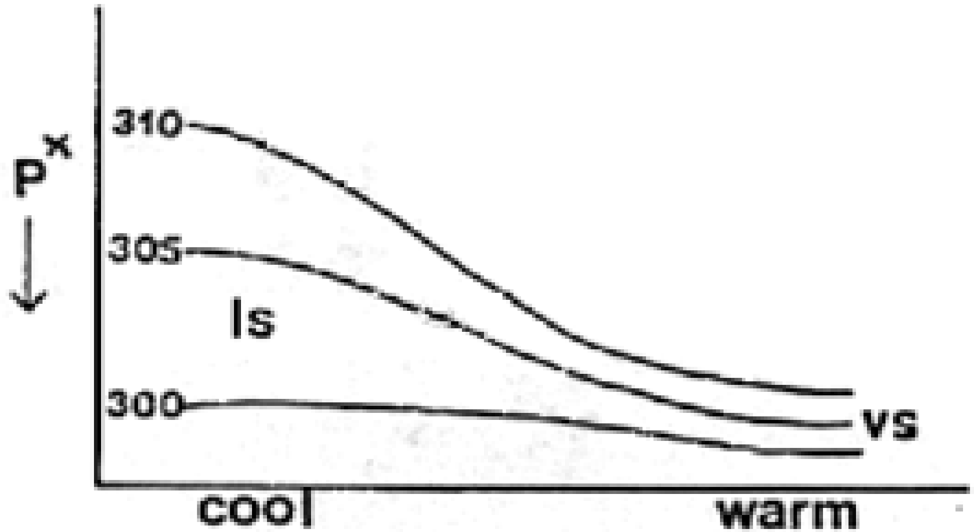


Figure 6. Cross section showing how the vertical resolution of an area may vary within a very stable (VS) and less stable (LS) region.

Neutral-Superadiabatic Lapse Rates

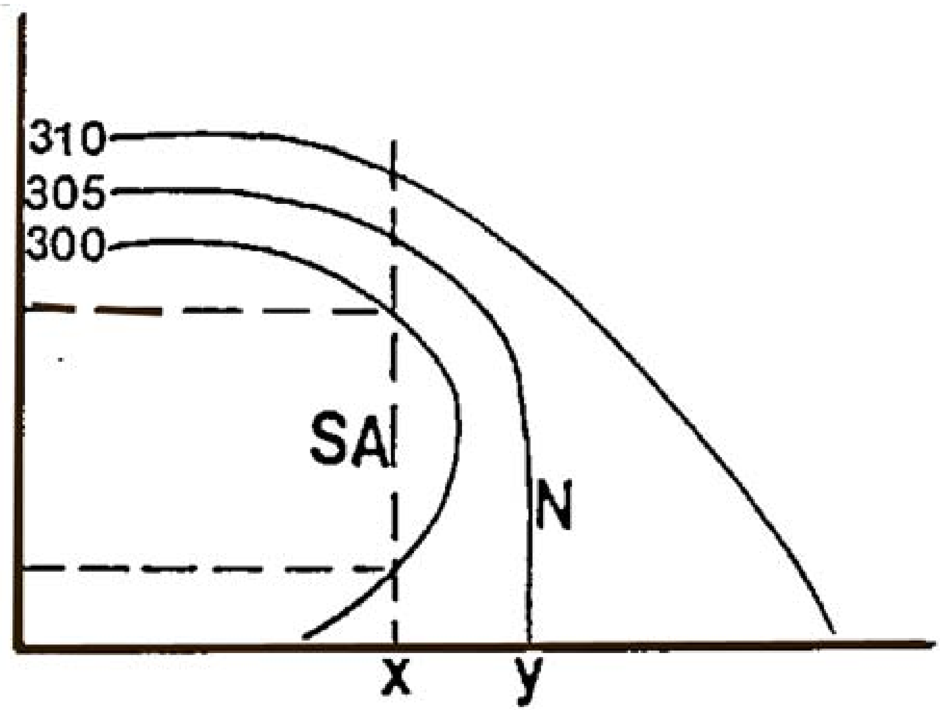


Figure 5. Cross section showing how isentropic surfaces appear in the vicinity of regions with superadiabatic (SA) and neutral (N) lapse rates.

Advection of Moisture on an Isentropic Surface

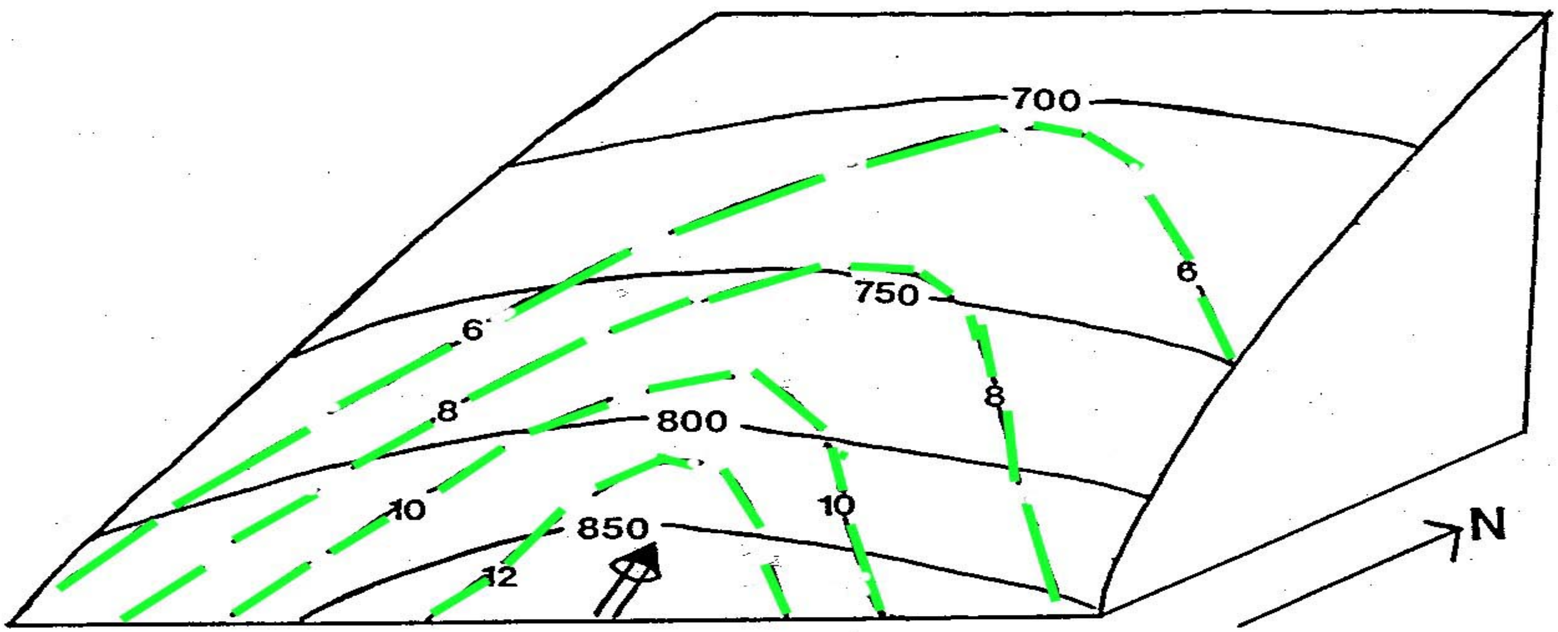


Figure 2b. Schematic depiction of isentropic surface along north-south line shown in Fig. 2a, east of short wave trough. Solid lines are isobars (mb), dashed lines are isohumes (gm kg^{-1}) and open arrow indicates the direction of flow along the isentropic surface.

$$\omega = \frac{dp}{dt} = \left(\frac{\partial P}{\partial t}\right) + \vec{V} \bullet \nabla P + \frac{d\theta}{dt}\frac{\partial P}{\partial \theta}$$

A **B** **C**

Term A: local pressure change on the isentropic surface

Term B: Advection of pressure on the isentropic surface

Term C: Diabatic heating/cooling term (modulated by the dry static stability.

Typically, at the synoptic scale it is assumed that terms A and C are nearly equal in magnitude and opposite in sign.

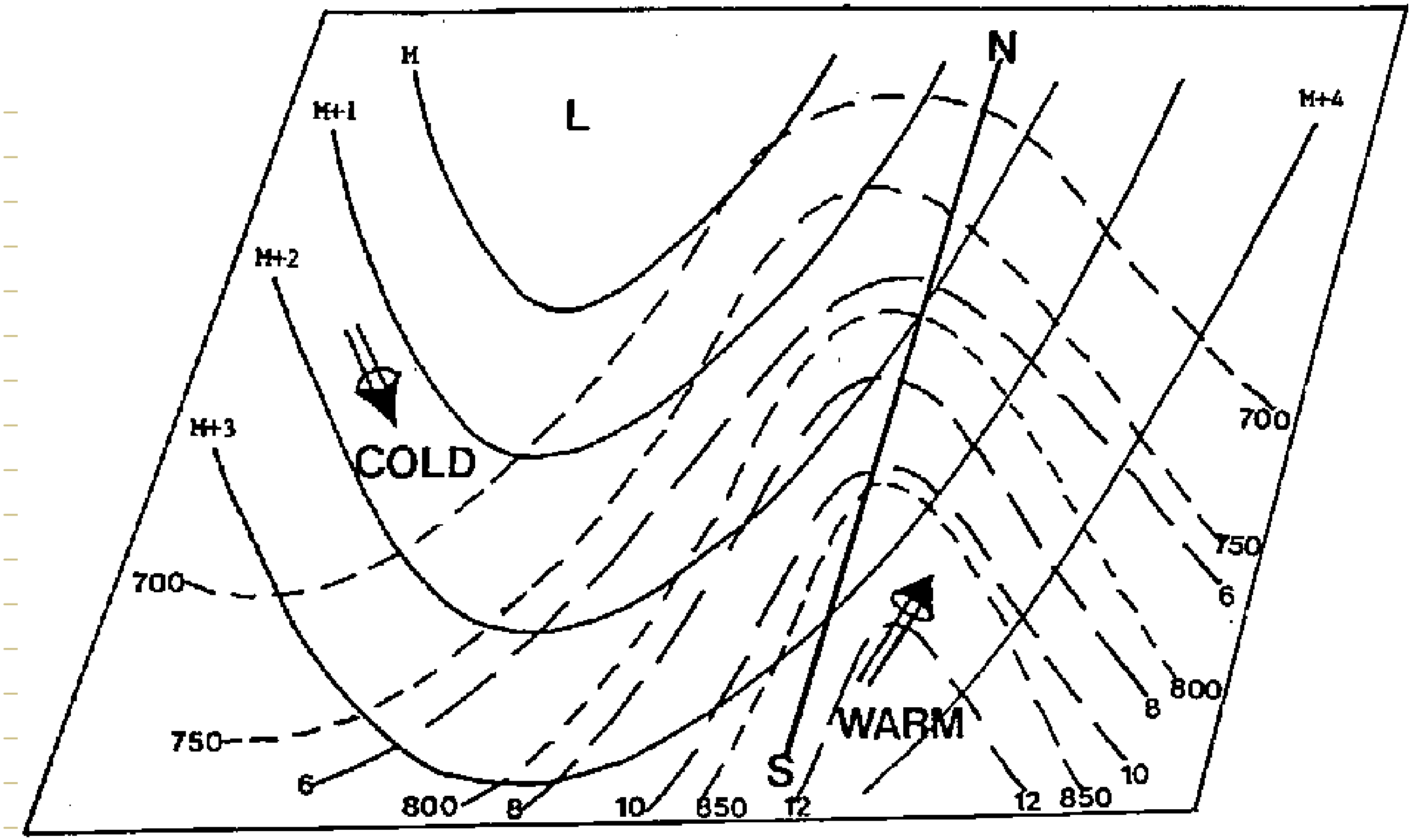


Figure 2a. Schematic depiction of 310 K isentropic surface. Solid lines are Montgomery streamfunction (10^1 J kg^{-1}), short dashed lines are isobars (mb) and long dashed lines are isohumes (gm kg^{-1}). Cross section shown in Fig. 2b is taken along bold, solid north-south oriented line.

Isentropic Analysis: Advantages

- For synoptic scale motions, in the absence of diabatic processes, isentropic surfaces are material surfaces, i.e., parcels are thermodynamical bound to the surface
- Horizontal flow along an isentropic surface contains the adiabatic component of vertical motion often neglected in a Z or P reference system
- Moisture transport on an isentropic surface is three-dimensional - patterns are more spatially and temporally coherent than on pressure surfaces
- Isentropic surfaces tend to run parallel to frontal zones making the variation of basic quantities (u,v, T, q) more gradual along them.

Isentropic Analysis: Advantages

- Atmospheric variables tend to be better correlated along an isentropic surface upstream/downstream, than on a constant pressure surface, especially in advective flow
- The vertical spacing between isentropic surfaces is a measure of the dry static stability. Convergence (divergence) between two isentropic surfaces decreases (increases) the static stability in the layer.
- Parcel trajectories can easily be computed on an isentropic surface. Lagrangian (parcel) vertical motion fields are better correlated to satellite imagery than Eulerian (instantaneous) vertical motion fields.

Isentropic Analysis: Disadvantages

- In areas of neutral or superadiabatic lapse rates isentropic surfaces are ill-defined, i.e., they are multi-valued with respect to pressure;
- In areas of near-neutral lapse rates there is poor vertical resolution of atmospheric features. In stable frontal zones, however there is excellent vertical resolution.
- Diabatic processes significantly disrupt the continuity of isentropic surfaces. Major diabatic processes include: latent heating/evaporative cooling, solar heating, and infrared cooling.
- Isentropic surfaces tend to intersect the ground at steep angles (e.g., SW U.S.) require careful analysis there.

Isentropic Analysis: Disadvantages

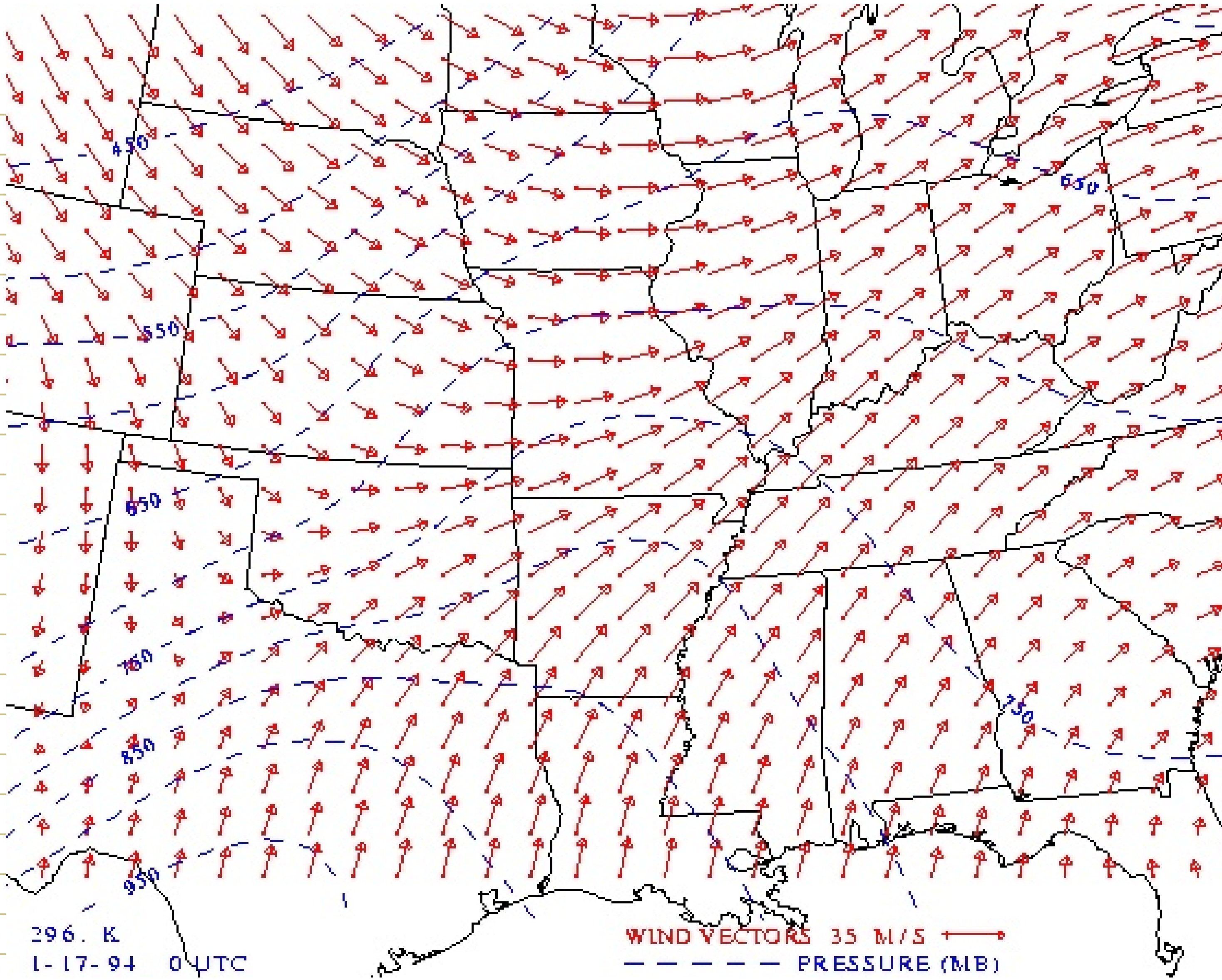
- The “proper” isentropic surface to analyze on a given day varies with season, latitude, and time of day. There are no fixed level to analyze (e.g., 500 mb) as with constant pressure analysis.

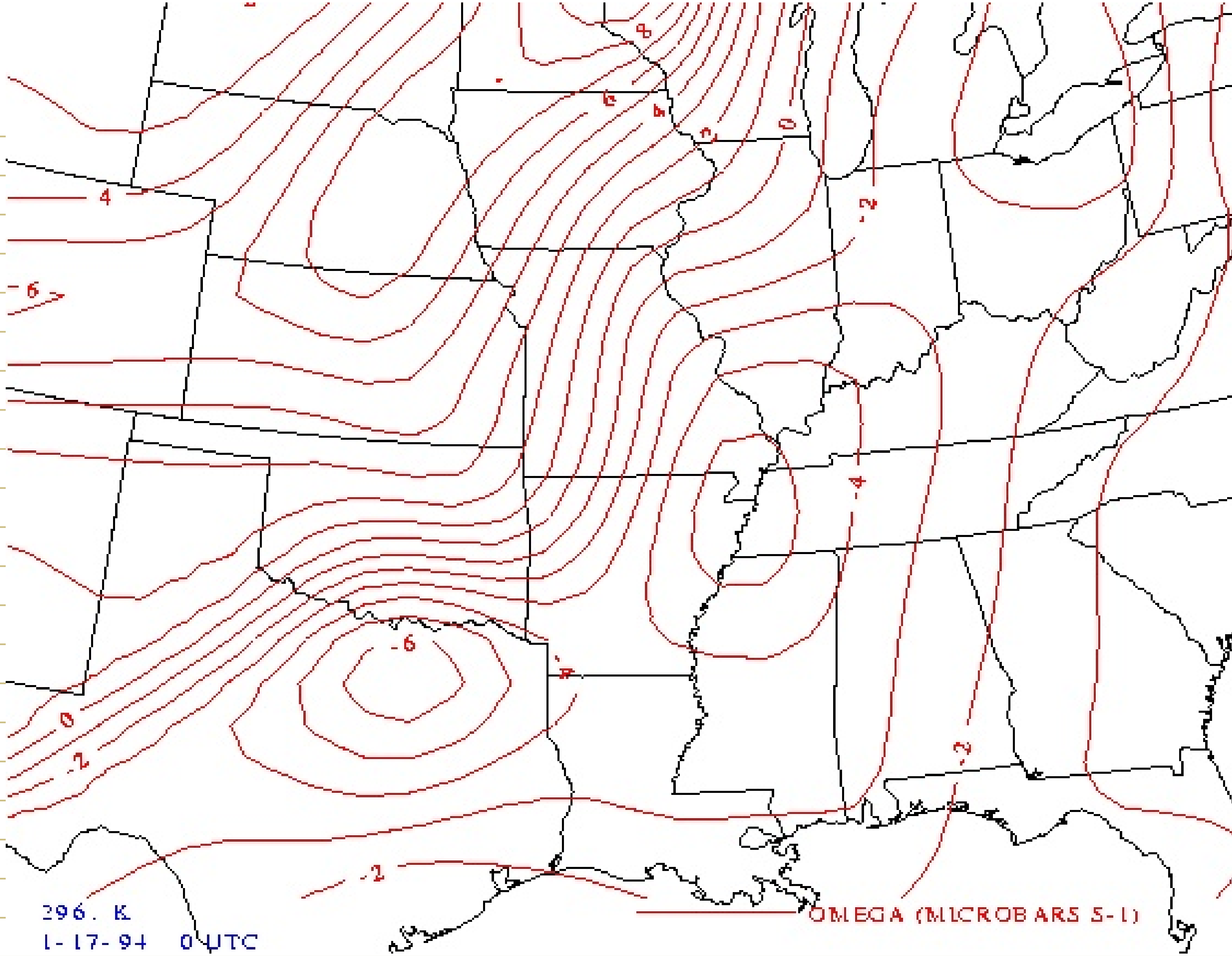
- If we practice “meteorological analysis” the above disadvantage turns into an advantage since we must think through what we are looking for and why!

Choosing the "Right" Isentropic Surface(s)

- The "best" isentropic surface to diagnose low-level moisture and vertical motion varies with latitude, season, and the synoptic situation. There are various approaches to choosing the "best" surface(s):
- Use the ranges suggested by Namias (1940) :

Season	**Low-Level Isentropic Surface**
Winter	290-295 K
Spring	295-300 K
Summer	310-315 K
Fall	300-305 K


450
550
650
750
850
950
650
750
296. K
1-17-94 0 UTC
WIND VECTORS 35 M/S
PRESSURE (MB)


296. K
1-17-94 0 UTC
OMEGA (MICROBARS S-1)