Mesoscale ConvectiveVortices (MCVs)

What is an MCV

- Mature MCCs are distinguished by 3 major dynamical features:

1) An upper-level anticyclone
2) a mid-level cyclonic vorticity center with lift
3) A cold pool at low-levels and an associated mesohigh there

The upper level anticyclone tends to be shallow and short-lived. However, the mid-level cyclone may persist long after the convection and precipitation have dissipated. These mesoscale convective vortices (MCVs) are small compared to the radiosnde network and are thus best identified using satellite imagery.

- Redevelopment of convection is a key reason why we study MCVs
- Bartels and Maddox (1991) MWR is good article on these – satellite picture shown in Figs 1 and 2
- Environment usually has low shear, low wind, usually near ridge (Bartels figs 8,9)
- < 5% of MCSs produce identifiable MCV
- Mechanism is mid-level inflow (f▼**V**)

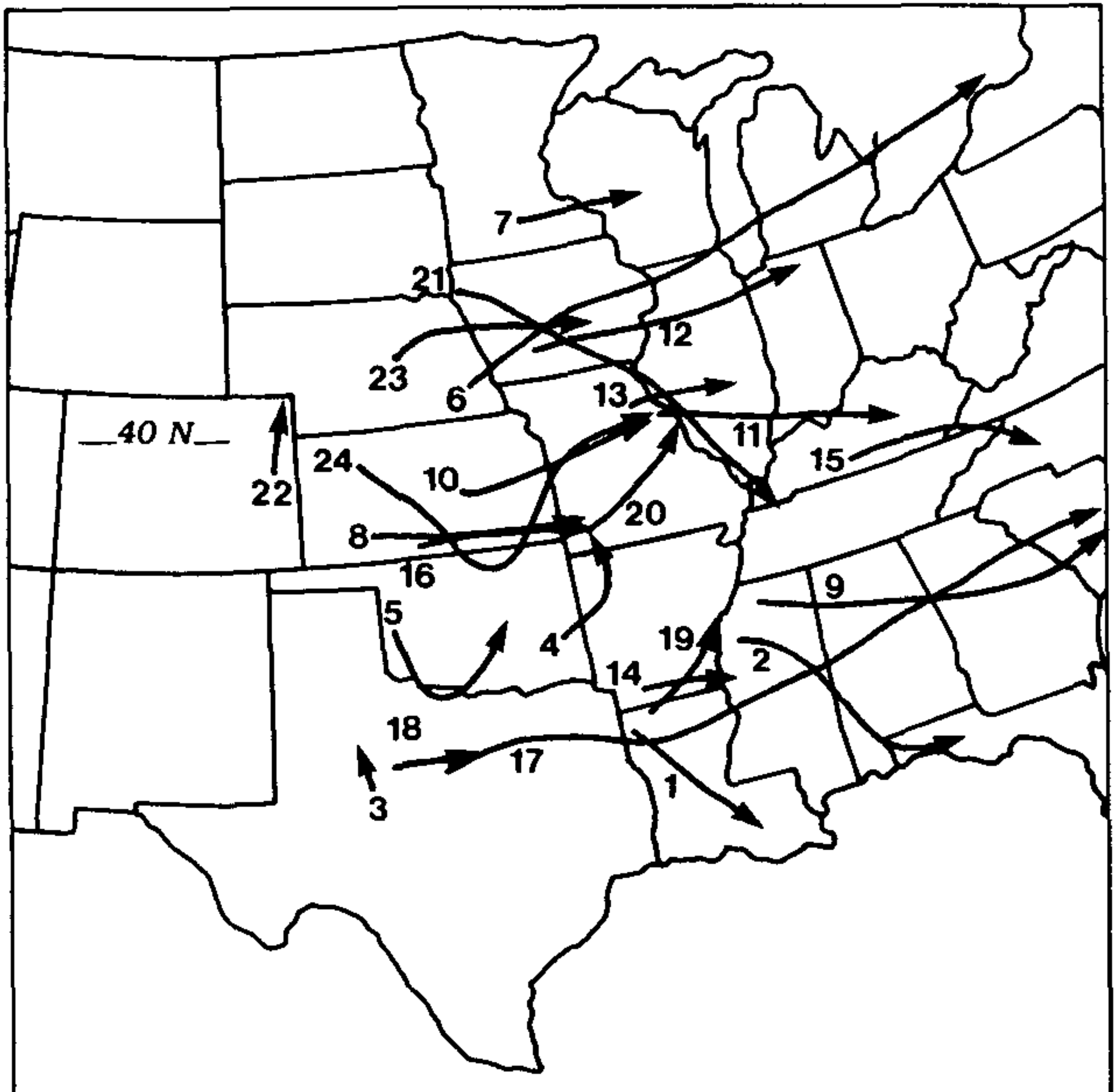


FIG. 5. Tracks of MCV centers. Case numbers correspond to those listed in Table 2.

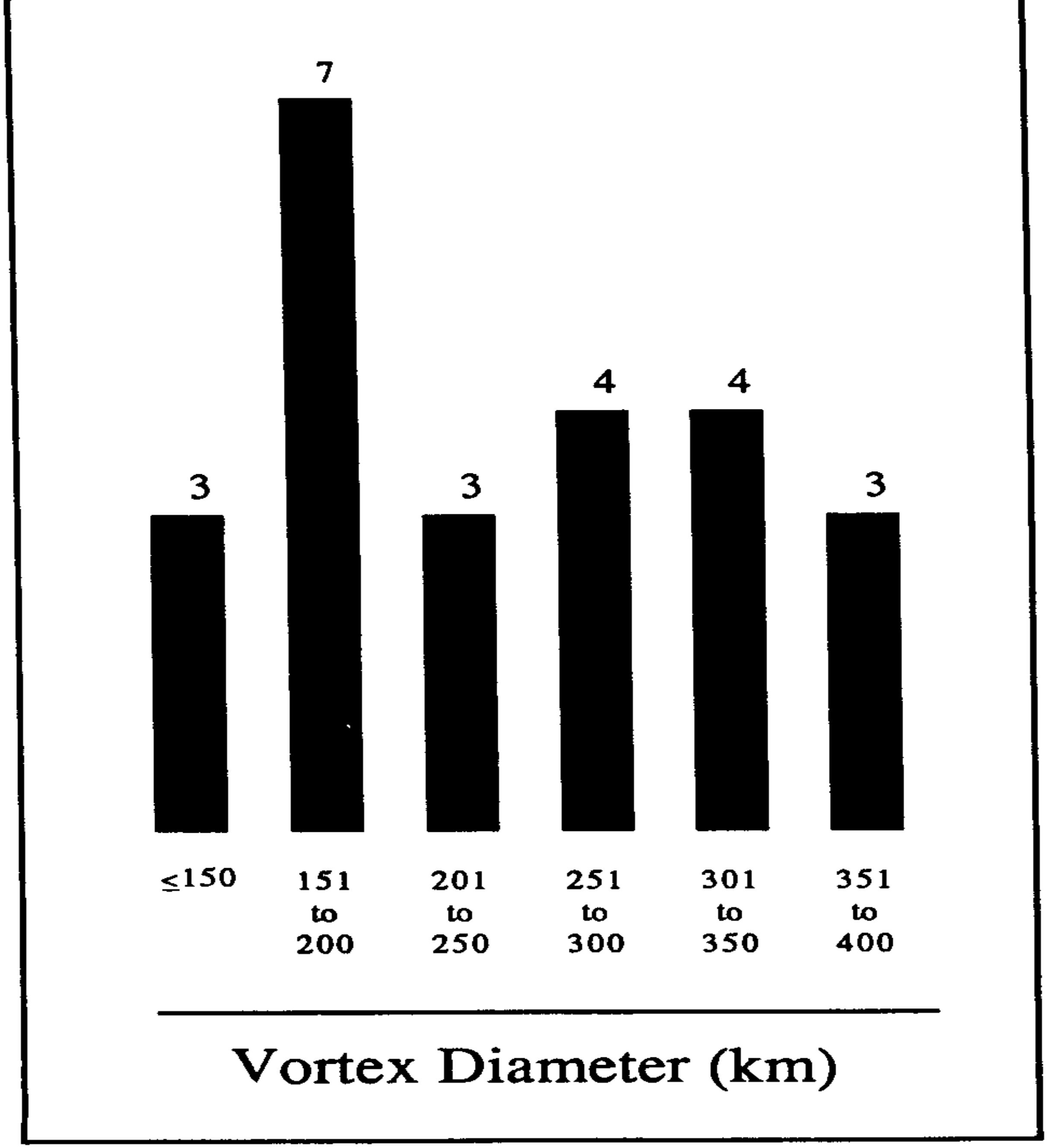


FIG. 7. Range of sizes of MCVs indicated by number of MCV cases versus diameter (km).

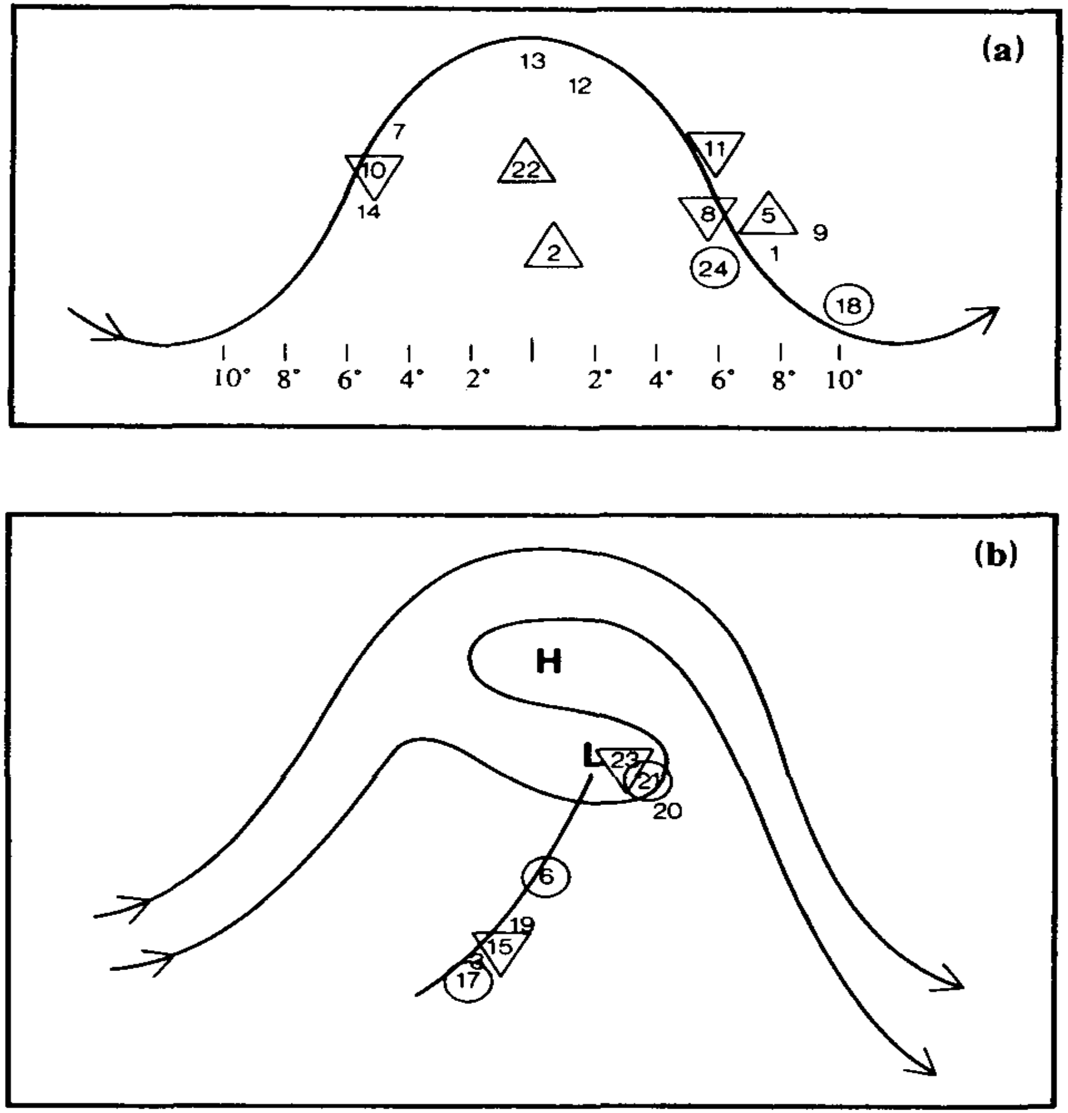


FIG. 8. Degree of subsequent activity associated with each MCV event is shown symbolically: case number alone indicates no activity, triangle = few cells, inverted triangle = MCS, and circles = a series event. (a) Location (expressed in degrees of longitude from ridge axis) of MCV events relative to 500-mb large-scale flow and ridge. Note an average scale of the ridge is 30° longitude. (b) Location of MCV events associated with a 500-mb blocking pattern.

Dynamical organization

- The persistence of the MCC can be to some extent related to its ability to generate a balanced circulation. In the theory of geostrophic adjustment an important length scale is the Rossby radius. For the basic state,

$L_R = c_g/f$ where c_g is the gravity-wave phase speed and f is the Coriolis parameter. This is a relationship between the removal of energy by gravity waves versus geostrophic adjustment

For systems with rotation, we have (from Schubert et. al):

$L_R = c_g /[(f+\zeta)^{1/2} (f+2V/R)^{1/2}]$

This indicates that the presence of vorticity/rotation acts to increase the efficiency with which a pressure perturbation generates a balanced flow.

(Note that 2V/R is the relative vorticity for solid-body rotation. Atmospheric circulations often do not experience solid-body rotation, i.e., the inner and outer parts of the system rotate at different rates.)

It is difficult to calculate cg but typical values are 30-50 m/s. Cotton et al. took cg about 30 m/s to get $L_R \approx 300$ km. They found that the MCC radius (from the -33 C cloud shield) was $\approx L_R$; slightly $> L_R$ for the well-developed MCCs and slightly $< L_R$ for the marginal ones.

We see therefore that the longevity of the MCC is likely to be promoted by its large spatial scale: the pressure perturbations induced by latent heating are not completely dissipated by gravity waves, but rather the scale is large enough that a balanced circulation may be developed.

Thus, the organized release of latent heat in the MCC initial phase is important to later development

Heat and Moisture Budgets of MCCs

- In tropical meteorology, a common diagnostic computation is the apparent heat source, and apparent moisture sink, usually referred to as Q_1 and Q_2. The apparent heat source is defined as:
- $Q_1 = \partial s/\partial t + \blacktriangledown sV + \partial s\omega/\partial p = Q_R + L_v(c\text{-}e) + (L_v+L_f)(d\text{-}s) + L_f\,(f\text{-}m) - \partial/\partial p(s'\omega')$

Where $s=c_pT+gz$ is the dry static energy, Q_R is radiative flux divergence, c=condensation, e evaporation, d deposition, s sublimation, f freezing, and m melting rates, and $s'\omega'$ is turbulent flux of s (prime is deviation from a meso-α scale average)

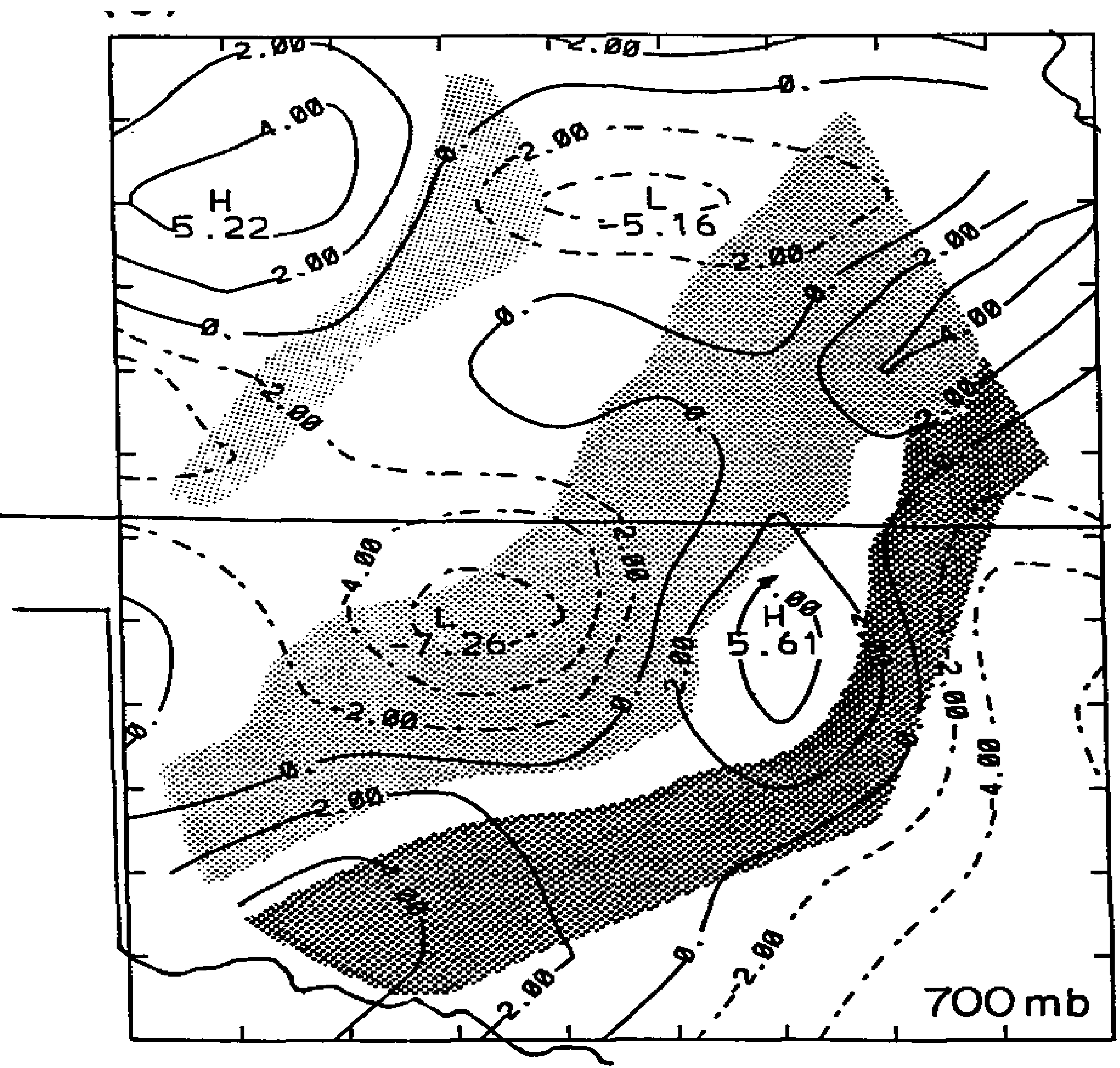
- Apparent moisture sink is defined as:

$Q_2 = -L\,[\partial q/\partial t + \blacktriangledown qV + \partial/\partial p(q\omega)] = L_v(c\text{-}e) + L_v\,(d\text{-}s) + L\partial/\partial p(q'\omega') + L_v \blacktriangledown q'V'$

Notice that the local tendency can be usefully interpreted as a “storage” term. Also note that $\partial/\partial p(s\omega)$, $(q\omega)$, i.e., without primes, includes both the mean and fluctuating parts of the vertical flux.

The Q1 budget at the initial stage is dominated by the horizontal advection term in the lower atmosphere and by the vertical advection term above ≈ 750 mb. This again points to the importance of the LLJ in the initial stages

The Q2 budget is dominated by the vertical advection term throughout the atmosphere. Notice that there is a moderate low-level moisture source (i.e., negative sink) due to horizontal advection.


H
5.22
L
-5.16
L
-7.26
H
5.61
700 mb

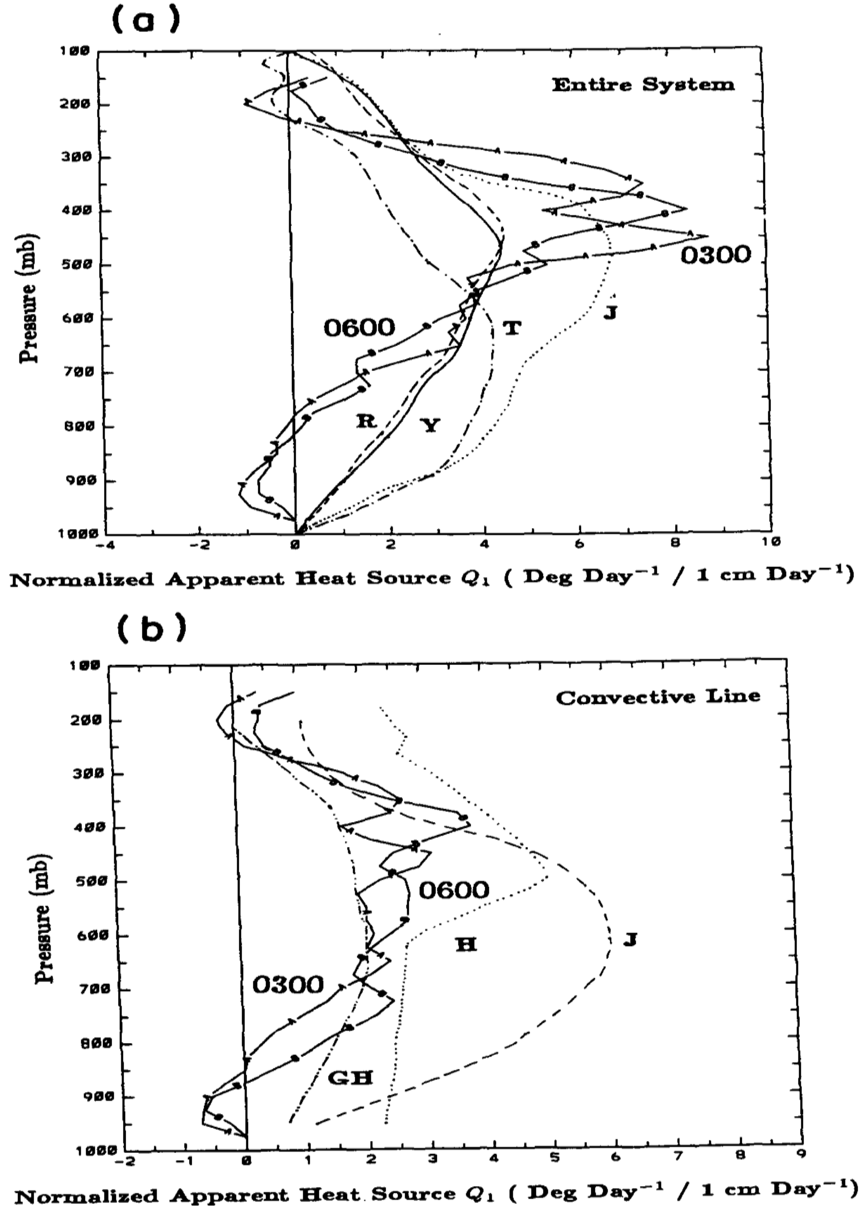


FIG. 9. Comparison of vertical Q_1 profiles normalized by rainfall rates for averages taken (a) over the entire system and (b) over the convective line region for 11 June at 0300 (curve A) and 0600 (curve B) UTC. In (a), other curves (from Johnson 1984) are from tropical or subtropical cases by Yanai et al. (1973, curve Y), Reed and Recker (1971, curve R), Thompson et al. (1979, curve T), and Johnson (1976, curve J). In (b), other curves (after Houze 1989) include an estimate from a simple cumulus model (Houze 1982, curve H), a residual inferred from rawinsonde data and stratiform region profiles (Johnson 1984, curve J), and a computation using diagnosed vertical velocities (Gamache and Houze 1985, curve GH).

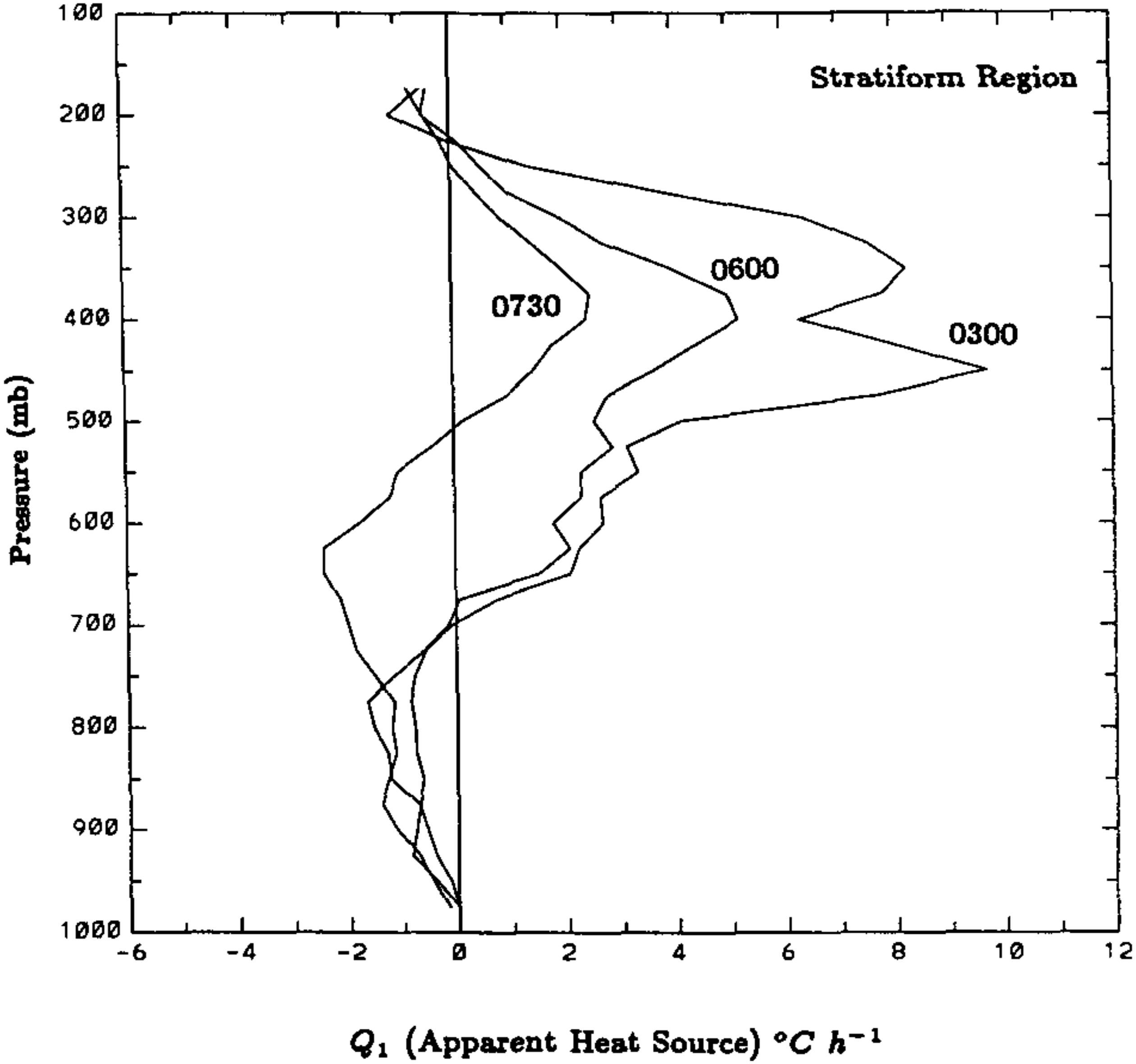


FIG. 10. Vertical Q_1 profiles averaged over the stratiform region of the 10–11 June squall line at 0300, 0600, and 0730 UTC.

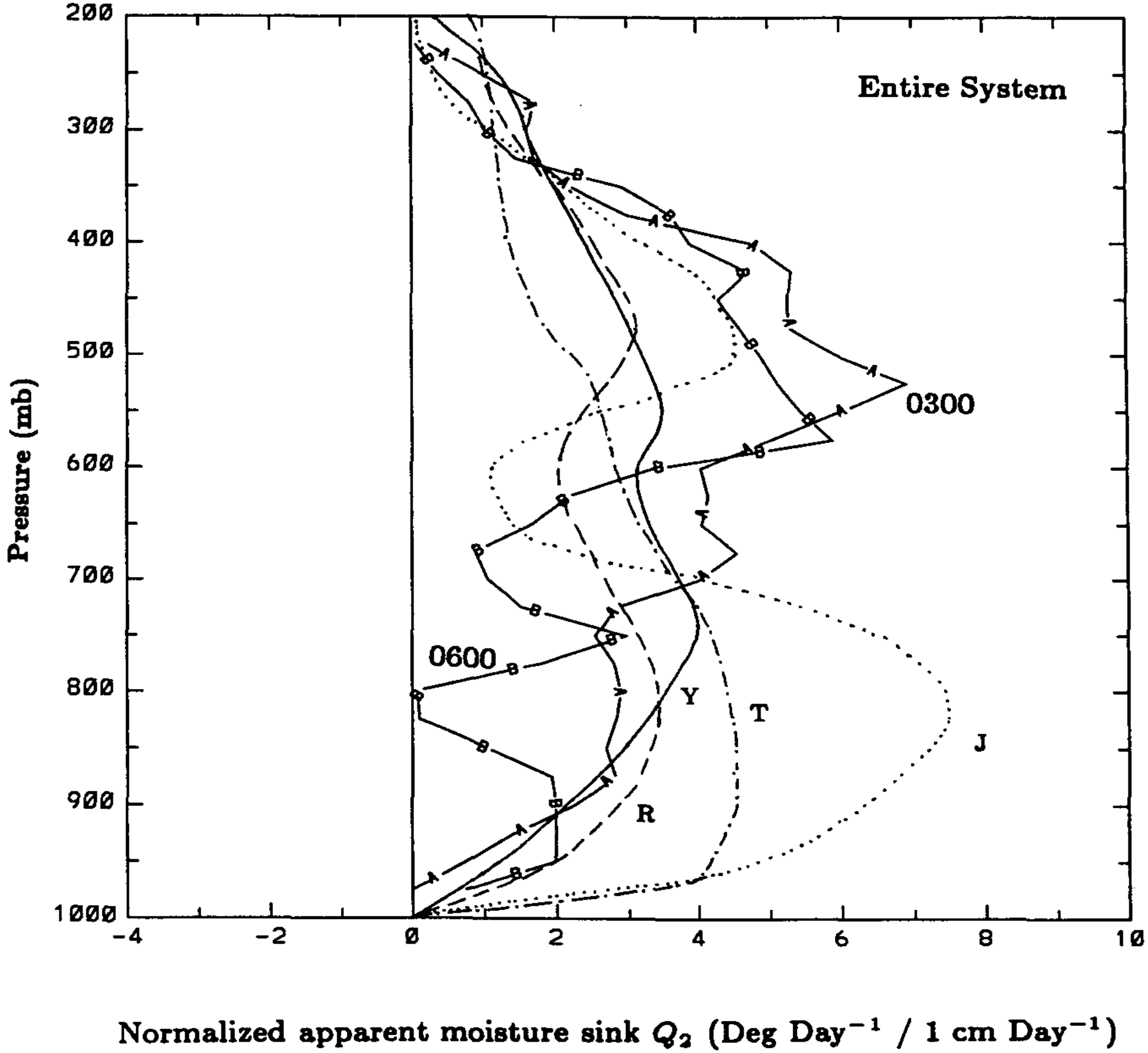


FIG. 13. Comparison of system-averaged vertical Q_2 profiles for 11 June at 0300 (curve A) and 0600 (curve B) UTC, normalized by the observed rainfall rate. Other Q_2 profiles (after Johnson 1984) are from Yanai et al. (1973, curve Y), Thompson et al. (1979, curve T), Johnson (1976, curve J), and Reed and Recker (1971, curve R).

TABLE 4. The water vapor budget and its comparison with observed precipitation during MCC evolution. Units in depth (mm) of liquid water per 3 h.

Subperiod	Term (1) $-q\nabla \cdot \mathbf{V}$	Term (2) $-\mathbf{V} \cdot \nabla q$	Term (3) $-\partial q/\partial t$	Terms (1 + 2 + 3) P-E	Observed P	Calculated E
Pre-MCC	1.505	1.227	−3.078	−0.346	0.580	0.926
Initial	1.238	0.464	−1.060	0.641	1.549	0.908
Growth	2.125	0.176	−0.712	1.589	2.614	1.025
Mature	1.620	−0.781	0.348	1.187	3.017	1.830
Decay	1.824	−0.357	−0.403	1.065	2.575	1.510
Dissipation	1.192	0.027	−0.716	0.503	1.545	1.042
Post-MCC	−0.119	0.268	−1.028	−0.879	0.967	1.846

advection

convergence

storage