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KINETIC ENERGY BUDGET STUDIES OF AREAS OF CONVECTION

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ABSTRACT

Synoptic-scale kinetic energy budgets are being computed for three cases when large areas of intense convection occurred over the Central United States. Major energy activity occurs in the storm areas.

INTRODUCTION

Kinetic energy budget studies have been performed mostly on synoptic-scale systems such as cases of cyclogenesis; few studies have dealt with mesoscale phenomena. Fuelberg (1977) and Fuelberg and Scoggins (1978) studied the energy variability of the synoptic-scale flow in which convection was imbedded. Large areas of intense thunderstorms seemed to influence the surrounding synoptic-scale environment. The present research involves additional studies of synoptic-scale kinetic energy variability during periods of intense thunderstorms.

THEORY

The kinetic energy equation in isobaric coordinates is:

$$\underset{(a)}{\frac{\partial K}{\partial t}} = \underset{(b)}{\int_{\sigma}\int_{p} -\vec{V}\cdot\vec{\nabla}\phi} - \underset{(c)}{\int_{\sigma}\int_{p} \vec{\nabla}\cdot k\vec{V}} - \underset{(d)}{\int_{\sigma}\int_{p} \frac{\partial \omega k}{\partial p}} + \underset{(e)}{\int_{\sigma}\int_{p} \vec{V}\cdot\vec{F}}$$

where $\int_{\sigma}\int_{p} = \frac{1}{g}\int\int\int dxdydp$, $\vec{F}$ is the frictional force, k is horizontal kinetic energy per unit mass, and A is the area of computation σ. Local changes in kinetic energy for a fixed volume, term (a) above, are due to four processes. Term (b) represents kinetic energy generation due to cross contour flow. Terms (c) and (d) are horizontal and vertical flux divergence of kinetic energy. Term (e), called the dissipation term, represents a transfer of energy between resolvable and unresolvable scales of motion.

PROCEDURES

Rawinsonde data are objectively analyzed onto a grid system that encloses the area of study. Gridded fields of the input data are obtained at the surface, and then at 50 mb intervals up to 100 mb. Vertical motions are computed using the kinematic method. By using finite difference techniques, values of the budget terms are computed at individual grid points at 50 mb intervals. Grid point fields of the budget terms are related to storm location, and the grid point values can be averaged in various ways.

Three case studies are being investigated--the first and second Atmospheric Variability and Severe Storm Experiments (AVSSE I, 27-28 April 1975; and AVSSE II, 6-7 May 1975) and the seventh Atmospheric Variability Experiment (AVE VII, 2-3 May 1978).

RESULTS

Kinetic energy budgets have already been computed for the AVSSE I and II periods. Brief results of these studies will be described.

a. The AVSSE II Period. During AVSSE II, intense thunderstorm activity formed in the Midwest and in central Texas along a dry line. To isolate energy processes near the convection from processes in non convection areas, grid point budget values were averaged to give kinetic energy budgets over small areas that just enclosed the convection. The budget areas moved as the convection moved.

Thunderstorm activity began near 1500 GMT 6 May 1975, reached peak intensity (18.6 km tops) and areal coverage near 2100 GMT, and had dissipated by 0300 GMT 7 May. The pressure-time cross-section of Fig. 1 indicates that average synoptic-scale vertical motion within the area was a maximum upward value ($\omega<0$) at 2100 GMT and later changed to downward motion. The literature suggests that diabatic heating associated with convection is probably responsible for inducing these changes. Fig. 1 also reveals that kinetic energy from the lower and middle troposphere is transported to higher levels of the atmosphere.

Dramatic changes in the kinetic energy budget also occur. Destruction of kinetic energy by cross contour flow (- values) near the level of the jet stream changes to strong generation of kinetic energy near 2100 GMT and then tapers off and changes sign (Fig. 2). Fuelberg and Scoggins (1978) observed similar variations in energy generation during AVE IV. Using mesoscale data, Tsui and Kung (1977) found that periods of active convection were times of strong generation of kinetic energy, but that destruction of kinetic energy was dominant near the time of storm passage.

The profile of horizontal flux divergence of kinetic energy at peak storm intensity (2100 GMT) is considerably different from that at earlier and later times (Fig. 3). Strong upper level export of energy (+ values) is dominant at 2100 GMT. The fluctuations in the transport term seen in the present case are similar to those observed during the AVE IV squall lines (Fuelberg and Scoggins, 1978).

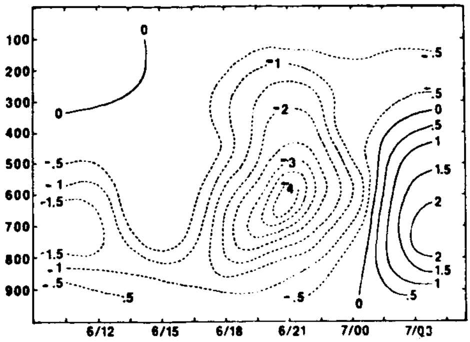

Fig. 1. Pressure-time cross section of vertical motion (ω) for the Texas convection area. $\mu b\ s^{-1}$.

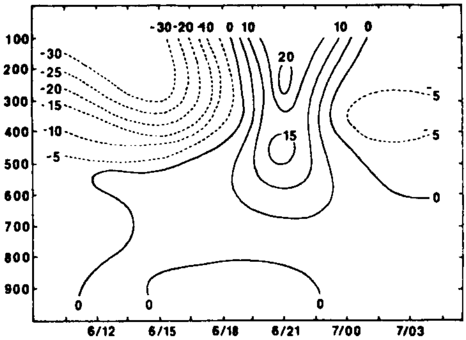

Fig. 2. Pressure-time cross section of term $-\vec{V}\cdot\vec{\nabla}\phi$ for the Texas convection area. W m^{-2}(100 mb)$^{-1}$

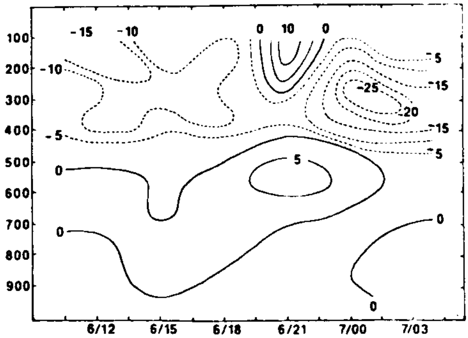

Fig. 3. Pressure-time cross section of term $\vec{V}\cdot k\vec{V}$ for the Texas convection area. W m^{-2}(100 mb)$^{-1}$.

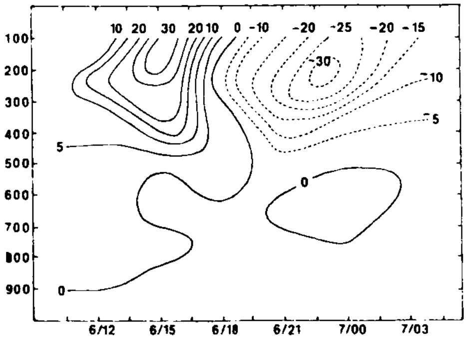

Fig. 4. Pressure-time cross section of the dissipation term for the Texas convection area. W m^{-2}(100 mb)$^{-1}$.

The dissipation term reveals that energy transfer between resolvable and unresolvable scales of motion is large in the synoptic-scale environment of the storms (Fig. 4). The net effect of all motions is a transfer of energy from resolvable to unresolvable scales (- values) after 1800 GMT. Before maximum storm intensity, the unresolvable scales of motion are a source of synoptic-scale kinetic energy.

A tabulated kinetic energy budget of this convection area is given in Table 1. Generation of kinetic energy by cross contour flow and dissipation to subgrid scales of motion are the two most important processes. The magnitudes of the energy processes occurring in the synoptic-scale environment of the convection are larger than those observed near many mature cyclones.

Table 1. Average kinetic energy budget for the limited area enclosing the convection in Texas at 2100 GMT 6 May 1975. The area is 1.5 x 10" m^2.

Layer (mb)	K ($10^5 Jm^{-2}$)	$\partial K/\partial t$ (Wm^{-2})	$\vec{\nabla}\cdot k\vec{V}$ (Wm^{-2})	$\partial\omega k/\partial p$ (Wm^{-2})	$-\vec{V}\cdot\vec{\nabla}\Phi$ (Wm^{-2})	D (Wm^{-2})
Sfc-700	0.5	-0.9	-1.2	2.0	1.0	-1.1
700-400	6.5	8.5	10.0	8.4	31.8	-4.9
400-100	24.1	2.6	5.9	-10.4	52.4	-54.4
Total	31.1	10.2	14.7	0.0	85.2	-60.4

b. The AVSSE I Period. A line of severe thunderstorms stretching from Nebraska into Texas formed along a cold front during the AVSSE I period. The results of this section demonstrate a different procedure by which the kinetic energy budget of storm areas is being investigated.

Values of Manually Digitized Radar (MDR) data are assigned to each grid point at each observation time. The average of each budget term is computed for various categories of MDR intensity by combining all observation times.

The average budget for grid points having no convection during AVSSE I is given in Table 2A while the average budget for grid points of moderate and intense convection (MDR 4-9 of the old MDR scheme) is given in Table 2B. Energy processes occurring during convection are much larger than those observed for non convection. The grid points associated with convection are characterized by strong destruction of kinetic energy by cross-contour flow and by transfer of energy from subgrid to grid-scale motions (positive dissipation).

c. Other Studies. Beside the results presented in this brief report, spatial fields of the energy budget terms are being examined for continuity and their relation to storm activity and other map features. Energy budgets for individual times of each case study are being compiled and examined for temporal var-

Table 2-A. Average kinetic energy budget for grid points having no convection during AVSSE I (26-27 April 1975). The number of grid points is 138.

Layer (mb)	K ($10^5 Jm^{-2}$)	$\partial K/\partial t$ (Wm^{-2})	$\vec{V}\cdot k\vec{V}$ (Wm^{-2})	$\partial\omega k/\partial p$ (Wm^{-2})	$-\vec{V}\cdot\vec{V}\phi$ (Wm^{-2})	D (Wm^{-2})
Sfc-700	2.7	-1.2	0.7	0.6	2.4	-2.3
700-400	7.1	1.5	8.1	0.6	9.2	1.0
400-100	14.4	4.4	-8.1	-1.2	-13.2	8.3
Total	24.2	4.7	0.7	0.0	-1.6	7.0
B. Kinetic energy budget for MDR 4-9 (43 grid points).						
Sfc-700	2.7	-0.8	0.0	2.6	-3.9	5.7
700-400	9.9	7.0	-7.6	9.4	-2.8	11.6
400-100	19.1	9.4	-4.8	-12.1	-35.6	28.1
Total	31.7	15.6	-12.4	0.0	-42.3	45.4

iability. Results of the AVE 7 period (May 2-3, 1978) also are being compiled.

CONCLUSIONS

The synoptic-scale kinetic energy budget of large areas of intense convection is considerably different from that of areas of non convection. Time series analysis of some budget terms suggests that the energy variability is closely related to the life cycle of the storms.

ACKNOWLEDGEMENTS

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