New Findings on the Apparent Relationship between Convective Activity and the Shape of 500 mb Troughs

TODD S. GLICKMAN

Massachusetts Institute of Technology, Cambridge 02139

NORMAN J. MACDONALD

Weather Services, Inc., Bedford, Mass. 01730

FREDERICK SANDERS

Massachusetts Institute of Technology, Cambridge 02139

29 March 1977

1. Introduction

In a recent paper, Macdonald (1976) demonstrated an association between cumulus convective activity and the tilt of the associated 500 mb trough away from a purely meridional orientation. Those oriented from northwest to southeast (negatively tilted) were associated with more frequent occurrence of thunderstorms and with larger precipitation amounts.

The interpretation of this result, however, is not clear. On the one hand, Starr and Rosen (1972) have argued that Rayleigh-like convection should produce an equatorward flux of westerly angular momentum, as is found typically in negatively tilted troughs. Thus the trough orientation is seen as a result of convection. On the other hand, it might be argued that synoptic-scale updrafts, forced principally by advection of heat and momentum, are more intense for these than for other types of troughs, and the convection is the result of release of potential instability in the lifted air. Thus the convection and heavy precipitation are seen as a result of the trough orientation.

In an attempt to resolve this ambiguity, we examined the synoptic-scale vertical motions produced by the six-level primitive equation (PE) model used operationally by the National Meteorological Center (Shuman and Hovermale, 1968). In this model, the vertical motions can be regarded as forced principally by heat and momentum advection, although they are not explicitly calculated that way. In particular, there is no representation of convective processes, other than the extremely crude moist-convective adjustment, applied where and when there is a coincidence of potential instability and sufficiently high relative humidity. Thus, the mid-latitude vertical motions in this model would correspond approximately to those in a world in which cumulus convection did not exist. The association of greater updrafts with negatively tilting troughs would support the second of the alternatives discussed above.

TABLE 1. Occurrences of vertical motion stratified by trough tilt in the midwest, summers of 1972 and 1973.

	Trough tilt		
	Positive	None	Negative
Upward	87	97	36
None	43	50	11
Downward	146	128	26

2. Data

In the summer, the vertical motion field is sufficiently weak that only the direction of the motion can be determined from the PE output. Thus, an examination was made of the qualitative direction of the vertical motion using data obtained from five stations in the area bounded by 35–45°N and 85–97.5°W: Omaha, Nebr.; Tulsa, Okla.; St. Louis, Mo.; Chicago, Ill.; and Nashville, Tenn. The days chosen were from the summers of 1972 and 1973, the same as those chosen by Macdonald. Table 1 shows the number of occurrences of upward, downward and zero vertical motion associated with positive, zero and negative tilting troughs. A chi-square test of the data shows that there is only a 4.7% chance that the two parameters, tilt and vertical motion are independent.

In the winter, the vertical motion field is more intense, allowing for estimation of the actual value of the vertical motion. In this case, the data were taken from five Great Lakes stations during the winters of 1971–1972 and 1973–1974. The stations selected were International Falls, Minn.; Sault Ste. Marie, Mich.; Buffalo, N. Y.; Detroit, Mich.; and Cleveland, Ohio. The dates chosen (as were the previous study's dates) were selected by a purely subjective "eyeball" estimation of a trough's existence in the region, and if so, its tilt.

Given a total of 696 cases, the grand mean over all dates and all types of tilts gives an average 700 mb vertical motion of 2.77×10^{-3} mb s^{-1}. Table 2 presents the data broken down into three groups for each positive, negative and no-tilt trough. In Fig. 1, the means are shown graphically with 95% confidence intervals. Of great importance is the fact that at the 95% level, the upward motion associated with the passage of a negative-tilt trough is significantly greater in magnitude than that associated with the presence of a positive-tilt trough.

3. Conclusion

These results support the view that the convection and heavy precipitation are a result of the 500 mb

TABLE 2. Upward motion in units of 10^{-3} mb s^{-1}, Great Lakes states, winters 1971–72 and 1973–74, related to trough tilt.

	Number of cases	Mean
All troughs	696	2.77
Positive tilt	287	0.96
No tilt	319	3.70
Negative tilt	90	5.56

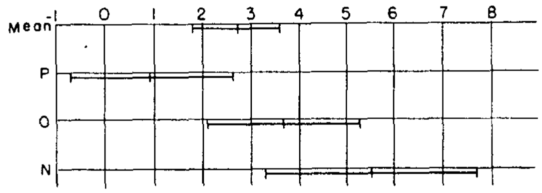

FIG. 1. Mean and 95% confidence intervals for P (positive), 0 (none), and N (negative) tilted troughs for Great Lakes states, winters 1971–72 and 1973–74. Vertical motion in units of 10^{-3} mb s^{-1}.

trough orientation rather than the cause of it. It could be argued, of course, that the trough orientation originally developed as a consequence of convection and then continued to support convection. We did not test this idea, but the question could be examined by evaluating the skill of the model in producing negatively tilted troughs. In any case, the association presented by Macdonald (1976) should have value in precipitation forecasting.

REFERENCES

Macdonald, N. J., 1976: On the apparent relationship between convective activity and the shape of 500 mb troughs. *Mon. Wea. Rev.*, **12**, 1618–1622.

Shuman, F. G., and J. B. Hovermale, 1968: An operational six-layer primitive equation model. *J. Appl. Meteor.*, **7**, 525–547.

Starr, V. P., and R. D. Rosen, 1972: A variance analysis of angular momentum in stellar and planetary atmospheres. *Tellus*, **24**, 73–87.