ON ENVIRONMENTAL CONDITIONS OF THE GENESIS OF TORNADO IN THE ZHUJIANG RIVER DELTA IN SPRING[①]

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ABSTRACT

Using observational data and the data of disastrous investigation of tornado in Zhujiang River Delta and Guangzhou's sounding from March to May of 1976-1983, the environmental conditions of genesis of tornado are analysed and compared with those of non-tornadic local storm. It is found that the favorable conditions of genesis of tornado are lower pressure, unstable stratification and stronger wind in the deep layer of troposphere and higher temperature and humidity in low level, among which, lower pressure, more unstable stratification and layer wind are primary conditions for a severe local storm to possibly develop into a storm with accompanying tornado. The tornado mechanism is not related to vertical wind shear.

Key words: : Zhujiang River Delta, spring tornado, environmental condition

Ⅰ. INTRODUCTION

The genesis and development of severe local storm are restricted by large-scale environmental conditions. There have been some researches on genesis conditions in low—middle latitude area in China (Tao, et al. , 1979; Wang, 1994). Tornado is a small-limits severe votex accompanying severe local storm and able to cause disaster. It is generally considered that the conditions of the genesis of the tornado are similar to those of thunderstorm, except that more unstable stratification is demanded (Yang, 1983). Apart from these, no more detailed analyses have been done about the conditions. In this paper, differences between tornado and severe local storm without accompanying tornado are investigated in details in Zhujiang River Delta in spring. The results are helpful for further understanding and improving of forecast tornado in low latitude of China.

Ⅱ. DATA AND ANALYSIS METHOD

The daily 00 : 00 GMT observational data and the disaster investigation data of tornado in Zhujiang River Delta (112.3-114.3°E, 22-24°N, 27 stations) and daily sounding data at 00 : 00 GMT in Guangzhou are used from March to May of 1976-1983. Severe local storm day is defined as the day when it occurs at least at one station and so is the heavy rain day.

Occuring too little statistically in summer, the tornadoes during that season are not invertigated in this paper. The frequence of tornado and the frequence rate of tornado to severe local storm are respectively shown in Table 1 and Table 2 for each month of

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spring, both being the highest in March and decreasing month by month, and two times more in March than in May.

Table 1. Monthly frequency of tornado in Spring.

Month	3	4	5
Number of tornado day	14	11	6
Frequence of tornado(%)	5.6	4.6	2.4

Table 2. Frequency ratio of tornado to severe local storm for each month of spring.

Month	3	4	5
Number of tornado days	14	11	6
Number of severe local storm	63	77	53
Ratio (%)	22	14	11

The environmental conditions of genesis of tornado are researched by analysing correlations between the tornado and parameters. Since tornado events are variables with (0,1) data and parameters, with continuous data, a statistic method, known as contrast (*CNT*), was developed by the author to describe their correlation, with $|CNT| \geqslant 0.2$ being defined as notable correlation of them (Wang, 1994, 1995), which is also used in the paper. Parameters selected are air pressure (geopotential height), temperature, humidity, wind and potential pseudo -equivalent temperature on standard pressure level, temperature lapse rate and wind shear between two levels and the difference of the potential pseudo-equivalent temperature between 700 hPa minus 850 hPa and 500 hPa minus 850 hPa. According to the data of entire set of days, the value of *CNT* of each parameter, as expressed by the correlation between it and tornado, is shown in Table 3, and for the value according to the data of severe local storm day, in Table 4. From Table 3 the environmental conditions of tornado genesis are identified and from Table 4 the differences between tornado and nontornadic storm in environmental conditions are identified.

Table 3. Contrast (*CNT*, %) of correlation between tornadoes and parameters.

Parameter	Month	Standard pressure level (hPa)							Air layer (hPa)				
		Surface	850	700	500	400	300	200	850-700	850-500	850/400	850/300	850/200
Pressure or height	3	**50**	**53**	**-39**	**-27**	**-34**	**-43**	**51**	—	—	—	—	—
	4	**-51**	**47**	**32**	**20**	-15	8	4		—	—	—	—
	5	**-30**	**-21**	-12	8	7	-4	2	—	—	—	—	—
Temperature and temperature lapse rate	3	18	**30**	17	**-28**	**45**	**38**	-14	**21**	**50**	**62**	**55**	**37**
	4	**32**	**31**	14	1	5	**22**	**34**	**28**	**29**	**25**	14	2
	5	**39**	**45**	**24**	11	9	17	12	**34**	**33**	**55**	**24**	**25**
Wind velocity and vertical wind velocity shear	3	13	**37**	**53**	**33**	**25**	**18**	**30**	17	1	0	-3	**22**
	4	10	19	**28**	**34**	**28**	6	17	13	17	13	-13	**-23**
	5	16	**29**	**38**	**36**	**35**	**28**	**37**	16	17	**21**	18	**25**

Dew-point	3	**27**	**44**	−7	−7	**21**	11	18	—	—	—	—	—
	4	**38**	**67**	**20**	−5	−1	−12	7	—	—	—	—	—
	5	**51**	**42**	11	−4	2	3	8	—	—	—	—	—
Dew-point depression	3	**−45**	**−30**	12	−3	**−38**	**−33**	**−29**	—	—	—	—	—
	4	**−30**	**−62**	−10	5	3	**20**	13	—	—	—	—	—
	5	**−24**	0	1	6	−6	4	−2	—	—	—	—	—
θ_{se} and $\Delta\theta_{se}$	3	19	**38**	9	**−21**	**−31**	**−37**	−14	**−36**	**−48**	—	—	—
	4	**35**	**53**	18	−5	1	19	**34**	**−48**	**−53**	—	—	—
	5	**44**	**44**	12	−2	−10	14	12	**−44**	**−53**	—	—	—

III. THE ENVIRONMENTAL CONDITIONS OF TORNADO GENESIS IN SPRING

The results from Table 3 are as follows:

(1) Tornado tends to occur at lower pressure in troposphere, its level and strength dropping month by month, the correlation of the pressure being notably negative on all level for March and below 850 hPa for May, the maximal value of *CNT* reaching −0.53 on 850 hPa for March and being −0.3 on surface for May. The common characteristic in March is notable negative correlation between tornado genesis and pressure, the convergence of depression offering fine triggering action for tornado.

(2) Tornado tends to occur at high temperature in low level and unstable stratification in troposphere. The positive correlations of temperature are significant below 850 hPa for each month. In addition, in March the negative correlations of temperature in middle and high level are significant too. So the positive correlation of temperature lapse rate in March is most marked, with the value of |CNT| reaching 0.62 in 850-500 hPa.

(3) Tornado has a tendency of being generated at the greater wind velocity in troposphere. In March and May, the correlations of wind velocity are almost evidently positive in 850-200 hPa, being most marked in March, with the value of *CNT* reaching 0.53 at 700 hPa, and in April, the most marked positive correlation occuring in 700-400 hPa. It can been seen that great horizontal momentum is favourable to tornado genesis.

(4) There in mechanism is no connection between tornado genesis and vertical wind shear. The |CNT| values of the shear are almost all less than the critical value, 0.2, below 300 hPa for each month. The correlations between the shear throughout cloud (from 850 to 200 hPa) and the tornado genesis are notably positive in March and May and notably negative in April, with all of the |CNT| much less than 0.25. It can be illustrated that there in mechanism is no connection for both.

(5) Tornado has a tendency of being generated in large humidity at low level. Below 850 hPa the correlations between dew-point and the tornado genesis are notably positive and dew-point depression, notably negative, with greater |CNT| values reaching 0.67 for the former and −0.62 for the latter on 850 hPa in April. It is shown that high humidity in low level is favourable to the genesis of tornado.

(6) Tornado tends to be generated in conditions of high potential pseudo-equivalent temperature in low level and notable potential instability in middle-low level. The positive values of *CNT* for the former are greater below 850 hPa for all month, which are caused by high temperature and greater humidity. The negative correlations between tornado genesis and the latter are marked for all month, which are caused by the strati-

fication with dry air above moist air or cold air above warm air. For example, in all monthes the values of CNT of the differences of potential pseudo-equivalent temperature of 500 minus 850 hPa and 700 minus 850 hPa are in range from −0.48 to −0.53. Therefore tornado is closely related to the potential instability in low-middle level.

To summarize, the large-scale environmental features for tornado genesis are varied markedly.

Ⅳ. THE DIFFERENCES OF GENESIS CONDITIONS BETWEEN TORNADO AND NONTORNADIC STORM

The above-mentioned conditions for tornado genesis in many respects are qualitatively identical to those of severe local storm in this area (Wang, 1994). But the favourable extent is different. It is stated that tornado is accompanied by more severe storm. To better understand their differences, the data of severe local storm days during three months have been merged with the total of the storm days being 193, of which the tornado days are 31. Table 4, which is from the data, shows that tornadoes are notably different from storms without accompanying tornado in the environmental conditions of their genesis. In comparison with nontornadic storm, the tornado tends to be formed under the conditions of lower pressure, greater wind velocity and more markedly unstable stratification in deep troposphere, greater humidity in low level and more marked potential instability. It is noteworthy that it is the three kinds of parameter, pressure, wind velocity and temperature lapse rate, that have much more notable effects than other ones. They have an important effect on the storm being developed more severely and generating tornado. But there is no marked difference for both in vertical wind shear.

Table 4. Contrast (CNT, %) of correlation between tornado and parameters according to the data of severe local storm days.

Parameter	Standard pressure level (hPa)							Air layer (hPa)				
	surface	850	700	500	400	300	200	850/700	850/500	850/400	850/300	850/200
Pressure or height	**−25**	**−35**	**−35**	**−27**	**−28**	**−28**	**−30**	—	—	—	—	—
Temperature and temperature lapse rate	−8	11	3	−16	**−30**	**−21**	−10	12	**31**	**43**	**33**	**22**
Wind velocity and vertical wind velocity shear	7	**28**	**38**	**35**	**33**	**20**	**22**	16	13	17	7	13
Dew-point	−3	**34**	−14	**−25**	−7	−18	−8	—	—	—	—	—
Dew-depression	**−30**	**−38**	16	19	−8	7	3	—	—	—	—	—
θ_{se} and $\Delta\theta_{se}$	−7	**23**	−7	**−24**	**−27**	**−21**	−10	**−38**	**−45**	—	—	—

Ⅴ. THE MEAN ENVIRONMENTAL CONDITIONS OF TORNADO GENESES AND NONTORNADIC STORM AND THEIR DIFFERENCES

In order to further show the environmental conditions of geneses of tornado and nontornadic storm and their differences, Table 5 is given. In Table 5, for both cases, the mean values of the parameters with the greatest |CNT| for the same kind of parameters as in Table 3 are given for each month. It can be seen from Table 5 that the differences of genesis conditions of both cases are significant, for example, in March the tornadic storm, as compared with the nontornadic storm, is 25 gpm less in the geopotential height of 850 hPa isobaric surface, 2.3℃ lower in 400 hPa temperature field, 0.07 ℃/100 m greater in temperature lapse rate between 850 and 400 hPa, 4.6 m/s greater in 700 hPa wind velocity and 7.5℃ less in the difference of potential pseudo-equivalent temperature etc. And the cases are similar between April and May. These mean values are of a certain reference significance to vocational works.

Table 5. Average values of parameters with largest |CNT| for tornadic and nontornadic storm on a monthly basis (1976—1983).

Most favourable parameter		P(hPa) or H(gpm)	T (℃)	Γ (℃/100m)	V (m/s)	T_d (℃)	$T-T_d$ (℃)	$\Delta\theta_{se}$ (℃)
Mar.	Location	850hPa	400hPa	850—400hPa	700hPa	850hPa	surface	850—500hPa
	Tornado	1491	−21.2	0.60	19.2	10.9	1.0	−6.0
	Nontornadic storm	1516	−18.9	0.53	14.6	9.4	1.8	1.5
Apr.	Location	surface	surface	850—500hPa	500hPa	850hPa	surface	850—500hPa
	Tornado	1009	21.6	0.55	20.5	15.6	1.1	−8.5
	Nontornadic storm	1013	20.1	0.51	16.7	12.1	2.8	0.3
May	Location	surface	850hPa	850—400hPa	700hPa	surface	surface	850—500hPa
	Tornado	1006	18.9	0.56	12.5	23.8	1.2	−5.3
	Nontornadic storm	1009	17.1	0.52	8.6	21.8	1.6	0.7

VI. CONCLUSIONS AND DISCUSSION

a. The environmental features of tornado forming are varied markedly in the area in Spring. The favourable conditions are lower pressure, greater wind speed and marked unstable stratification in troposphere, higher temperature and greater humidity in low level and notable potential instability in low-middle level. Qualitatively they are basically the same as ones of severe local storm. But tornado demands more favourable conditions than severe local storm does.

b. The frequency ratio of tornado to severe local storm is much higher in March than in April and May. And the correlations between tornado and the three kinds of parameter, i. e., pressure, wind speed and temperature lapse rate in deep troposphere, are much more remarkable in March than in April and May. And in all kinds of parameters they are of best correlation with tornado so as to relate the three cases to each other. It is considered that the main conditions for severe local storm to be further developed into more severe storm accompanying tornado are strong convergence of depression, greater horizontal momentum and marked unstable stratification.

c. The important effect of environmental wind on severe local storm being developed into tornado lies only in its wind speed, instead of its vertical shear, especially in low-middle level , the later in mechanism being not related to tornado genesis, which is not the same as present speculation that vertical wind shear is favourable to the development of the storm in middle latitude area. The important effect of wind velocity would be explained as follows:

(a) The greater the horizontal momentum of environmental air that is entrained into the downdraft of cloud in the process of convective development, the stronger the surface wind enhanced by momemtum transfered in downdraft.

(b) There is close link between the scale of storm and the wind velocity near the storm base. The greater the velocity in low-middle level, the larger the scale, as entrainment rate is inversely proportional to the scale, and the weaker the "dilute" effect of buoyancy and moisture from the entrainment of environmental air, which is therefore more favourable for the development of the storm. The result has been numerically simulated by an one-dimensional, steady -state model of cumulus, of which cross section varies with height (Wang, 1993).

(c) Greater wind velocity may be related to jet that has important effect on generation of severe convective weather.

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