SYNOPTIC CLIMATOLOGY OF TORNADO ENVIRONMENTS IN FINLAND

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(Dated: 15 September 2009)

I. INTRODUCTION

Setting up an effective tornado warning process, requires, among other aspects (e.g., Rauhala and Schultz 2009), knowledge of the environments favourable for tornadic storms. Recognizing such a weather pattern may help to forecast the potential for severe weather days in advance. If storms develop in an environment favourable for tornadoes, tornado warnings may be issued significantly in advance, compared to if only radar detectable severe storm signatures or spotter reports are used.

Although severe-storm forecasting parameters have been widely used in forecasting, they have many weaknesses (Doswell and Schultz 2006). A better approach to forecasting deep moist convection and its associated severe weather is through the ingredients-based approach. To best prepare forecasters for 1–3-day forecasts of severe-weather potential, forecasters will want to know the most common ways that these ingredients are brought together for a given region. The purpose of this paper is to determine what weather patterns bring together the ingredients for convective storms that produce tornadoes in Finland.

II. DATA AND METHODS

We used a climatology containing 253 tornadoes and 184 tornado days in Finland (1948–2007). The environment of each tornado day was characterized by data from the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalyses (Kalnay et al. 1996) plotted from the Web page at the Physical Sciences Division (PSD) of the NOAA/Earth System Research Laboratory. For each tornado day, the reanalysis data at the time (0000, 0600, 1200 or 1800 UTC) preceding the first tornado observation was used. For each tornado day, 300-hPa, 500-hPa, 850-hPa and surface maps were produced, and they were clustered manually into four distinct tornado environments, plus an unclassified category (Doswell 1991).

To produce composite synoptic maps, the PSD Web page was used to create composites from the NCEP–NCAR reanalyses. For the synoptic composite figures presented in this paper, we used only the significant (F2+) tornadoes of each class. Observed tornado locations of significant tornado days are plotted on the figures.

III. SYNOPTIC PATTERN COMPOSITES

a. Class A synoptic pattern

The most common tornado environment is Class A with 27% (50) of the 184 all-tornado days in Finland. This pattern included 33% (10) of the 30 significant-tornado days. The pattern is characterized by a westerly or southwesterly 300-hPa jet southwest of Finland (Fig. 1). The tornadoes form in the jet-exit region. An 850-hPa low-level jet stream is parallel to the upper-level jet. A 500-hPa large-scale trough is situated over Scandinavia or the Norwegian Sea. An area of low surface pressure is west of Finland resulting in strong west to south surface winds.

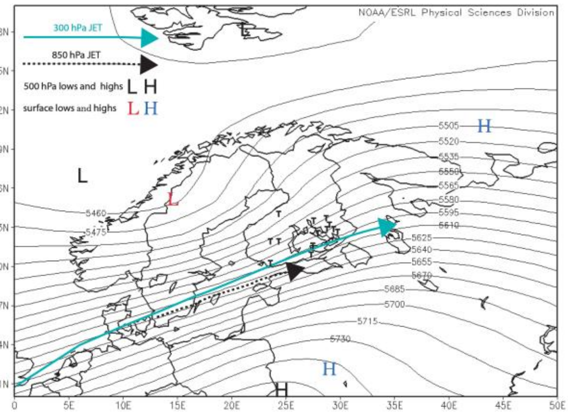

FIG. 1: Class A synoptic composite chart. Solid lines are the composite mean of 500-hPa height. Tornado locations during significant-tornado days in this class are denoted by T.

b. Class B synoptic pattern

The second pattern includes 13% (24) of all-tornado days and 20% (6) of the significant-tornado days. It is characterized by a strong low both at surface and at 500 hPa, south or southwest of Finland, resulting in easterly or southeasterly flow at both heights (Fig. 2). The primary feature of this pattern is a southeast–northwest-oriented 300-hPa jet axis slightly south of the tornado area. At 850 hPa, a southeasterly low-level jet stream advects warm air from Russia to the tornado area.

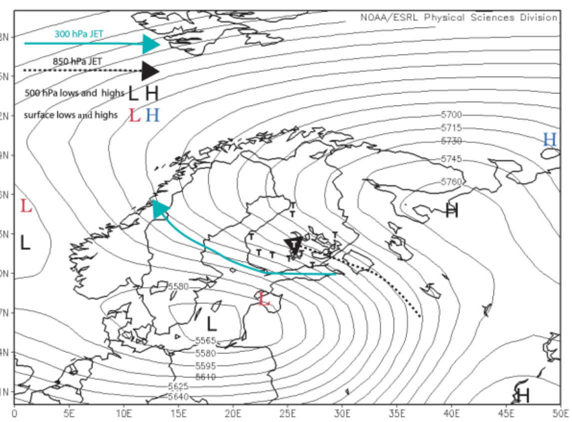

FIG. 2: As in Fig. 1, except for Class B synoptic composite chart.

c. Class C synoptic pattern

The Class C pattern includes 11% (21) of all-tornado days and 10% (3) of significant-tornado days. The tornadoes form in the 300-hPa jet right entrance region, west of the southerly or southeasterly low level jet (Fig. 3). A 500-hPa large-scale trough is situated west of Finland at the Norwegian Sea or Scandinavia, and the surface low center is west of Finland often with a secondary low just southwest of the tornado area. Also, a tongue of warm 850-hPa air travels from the south and southeast to southeastern Finland.

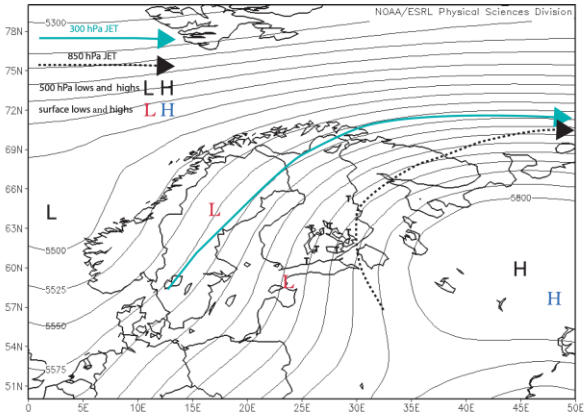

FIG. 3: As in Fig. 1, except for Class C synoptic composite chart.

d. Class D synoptic pattern

This pattern includes 7% (13) of all-tornado days and 10% (3) of significant-tornado days. This pattern is similar to Class A as the tornadoes form in the left-exit region of the westerly 300-hPa jet (cf. Figs. 1 and 4). The major difference is in the 500-hPa flow, which features a large-scale trough west of Finland in Class A and zonal flow in Class D (Fig. 4). Also, the 850-hPa wind maximum is located further south of the tornado area in Class D compared to Class A. The tornadoes form close to the rapidly eastward-moving surface low.

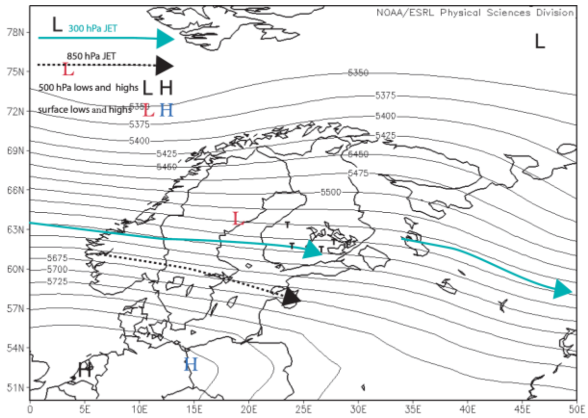

FIG. 4: As in Fig. 1, except for Class D synoptic composite chart.

IV. CONCLUSIONS AND RELATIONSHIP TO OTHER CLASSIFICATION SCHEMES

These four patterns classify 73% (22) of the 30 significant-tornado days in Finland since 1948, leaving 27% (8) cases unclassified. When all-tornado days are included, the number of unclassified cases increases to 41% (76) of all 184 cases. One explanation is that many of the weak tornadoes in this study have likely formed within non-supercell storms, which can form in a large variety of weather situations.

If we compare these four patterns to those observed in the United States (Miller 1972), most U.S. patterns show a much clearer wind veering with height than our patterns. Only in the Class C (Fig. 3) composite does the wind veer with height in the tornado formation area. The Class C pattern has similarities with Miller's Type B tornado-producing pattern as both have a low-pressure centre, a major upper-level trough and a frontal boundary west of the tornado area. The Class C tornadoes occurred in the right-entrance region of a jet streak, which supports both a low-level jet and synoptic-scale ascent.

The Class B pattern has similarities with Miller's Type D pattern with warm low-level air underneath a cold 500-hPa low, although our Class B pattern is rotated 45˚ counterclockwise relative to Miller's Type D pattern.

Both our Class A and Class D patterns are similar to Miller's Type E tornado-producing pattern with westerly 500-hPa flow and a surface low centre northwest of the tornado area. The Class A and Class D tornado cases occurred in the exit region of a 300-hPa jet streak, where the jet-streak circulation is associated with a low-level jet (Uccellini and Johnson 1979). According to Rose et al. (2004), based on their 10-yr climatology in U.S., tornadoes occur primarily in the jet-exit region, more commonly in the left-exit region than right-exit region.

The cases in Class A and Class C occurred in an upper-level southwesterly flow in front of an approaching 500-hPa trough. Similar results have been found by Rogash and Racy (2002) in significant tornadoes occurring in proximity to flash flooding.

V. ACKNOWLEDGMENTS

The composites were provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado, from their Web site http://www.esrl.noaa.gov/psd. David Schultz is partially funded by Vaisala Oyj.

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