Intermonthly Variability of Cyclone Tracks in the Mediterranean

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ABSTRACT

Objectively calculated monthly cyclonic tracks in the Mediterranean are presented. The intermonthly variations within each season are shown to be quite significant and are particularly notable for December–January, April–May and June–July. We suggest that composite seasonal pictures are not faithful representations of the cyclonic routes over a complex terrain region like the Mediterranean.

1. Introduction

It is most common in the literature to find descriptions of cyclonic tracks focused on seasonal variations, and in particular winter versus summer or spring versus autumn (Reiter 1975; Weather in the Mediterranean 1972). The justifications for such a general description are first, the minor intermonthly variations that are often found within each season, and second, the desire to have a concise picture of the cyclonic track climatology. This is true for global-scale cyclonic tracks (Petterssen 1956; Whittaker and Horn 1984; Lambert 1988; Wallace et al. 1988) and for regional studies such as in the Mediterranean (Reiter 1975).

It is the purpose of this note to focus on the month to month variations in cyclonic routes in the Mediterranean and to point out the significance of these changes for understanding climatological features in the region. We conclude not only that the seasonal composites are blurred pictures of climatological routes, but also that each month within its pertinent season exhibits its own track climatology, which cannot be directly deduced from interpolation of the seasonal pictures. The relative importance of interannual variability for a particular month will be briefly discussed.

In the present study we use the objective technique for defining cyclonic tracks suggested by Alpert et al. (1990). In the next section we describe the intermonthly changes within each season, while section 3 summarizes the main conclusions.

2. Monthly variation of cyclone tracks

The tracks presented here were objectively calculated based on ECMWF (European Centre for Medium-Range Weather Forecasts) initialized analyses for November 1982–December 1987 at 0000 and 1200 UTC. Possible effects owing to problems in the data assimilation system are discussed by Alpert et al. (1990). A cyclone was defined where a geopotential minimum was found in the 1000-mb analysis, and since a highly accurate parabolic/biparabolic interpolation scheme was used, 16 neighboring grid points were involved in defining each minimum location and geopotential height. The search for the track was oriented within an ellipse whose major axis is defined by the 700-mb wind vector. Alpert et al. (1990) describe the method in detail and indicate that about 90% of the cyclone routes analyzed subjectively are identified by the objective method. Every minimum was originally counted, but in the calculation of track densities per 2.5° × 2.5° box, we omitted tracks in that the distance between the starting and ending points was less than about one grid point (250 km). This has nearly eliminated all "heat" lows (as well as other quasi-stationary lows) in summer, in contrast to the cyclone frequencies reported in Alpert et al. (1990, section 2), where every minimum was included.

Figure 1 shows the average cyclone track density for December, January, and February. In general the three winter months are similar in that the major route is in the northern section of the Mediterranean, but some features are different. First, the cyclones do not leave the Mediterranean by the same routes. In December, most cyclones leave from the eastern Mediterranean (EM), frequently through the southeastern Mediterranean (at 32°N, 32°E; locally known as a Gaza Low) while fewer cyclones leave through the Aegean Sea (37°N, 25°E) towards the Black Sea (42°N, 35°E). In February, however, more cyclones leave through the latter route; i.e., from the Aegean Sea to the Black Sea. A third route, leaving the western Mediterranean (WM) from Italy (40°N, 15°E) to the northeast, appears only in February. This is probably related to the

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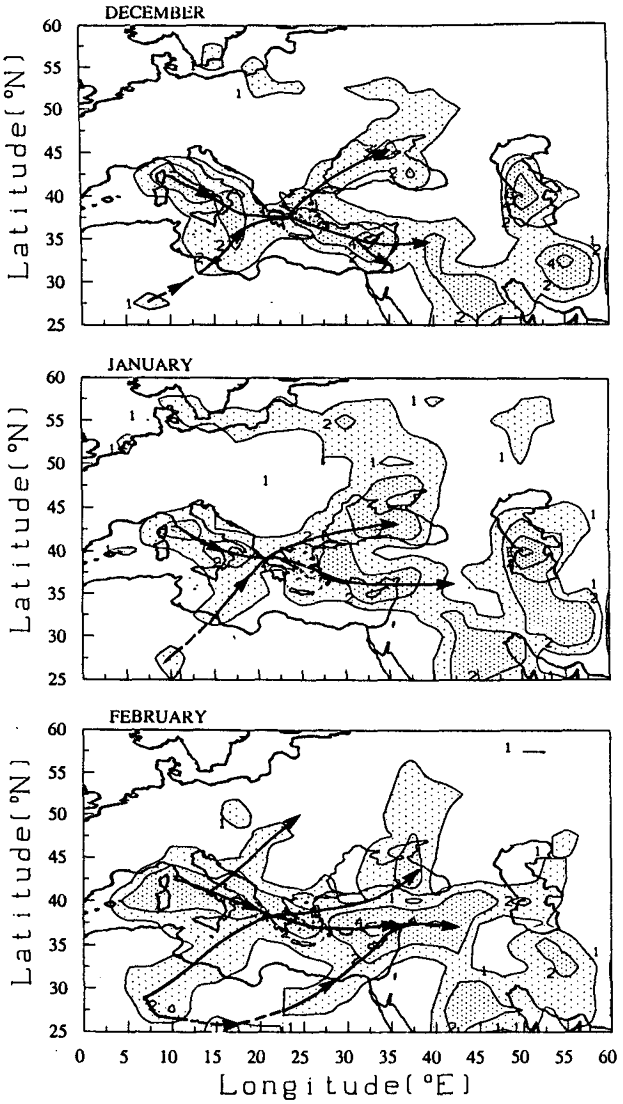

FIG. 1. Isolines of the average number of track occurrences in a 2.5° × 2.5° rectangle (i.e., cyclone track density) for winter months December, January, and February during November 1982–December 1987. Contour values of 1, 2, 4, 6, 10, etc., are plotted. Density of dotted shading increases for values above 1, 2, and 4, respectively. Major routes are schematically drawn based on the actual track maps; e.g., Alpert et al. (1990, Figs. 6, 7). Dashed route indicates, in general, a low track density (below 1) or sometimes, as for the eastern Mediterranean in June, slightly higher than 1 but with short broken tracks.

stronger thermal effect of higher sea surface temperatures in December. The tendency of the cyclones to penetrate the southern part of the EM particularly in early winter was discussed by Alpert and Reisin (1986).

A second feature that varies considerably through the winter is the north African cyclonic routes. In December–January the cyclones originate in the west near the Atlas Mountains (27°N, 10°E), and move to the northeast (32°N, 15°E) directly toward the western Mediterranean, but in February they tend to move along the north African coast with a more easterly track.

In the spring months of March, April, and May (Fig. 2) intermonthly changes in cyclonic routes are even more pronounced than in winter. First, the major transition of cyclonic tracks from the Mediterranean to the north African coast takes place as spring progresses. Whereas in March about an equal number of cyclones move along the Mediterranean and along the north African coast in April most cyclones move along the north African coast. [As shown by Alpert et al. (1990, Figs. 1–2), north African cyclone frequencies in winter are very low, and since short lived cyclones have been eliminated in the current study the winter to spring drastic change is *not* due to short lived cyclones.] The north African depressions (also called Saharan Depressions or Sharav Cyclones) originate at the lee of the Atlas Mountains, northwest Africa (27°–32°N, 5°–10°E), move primarily to the east in March,

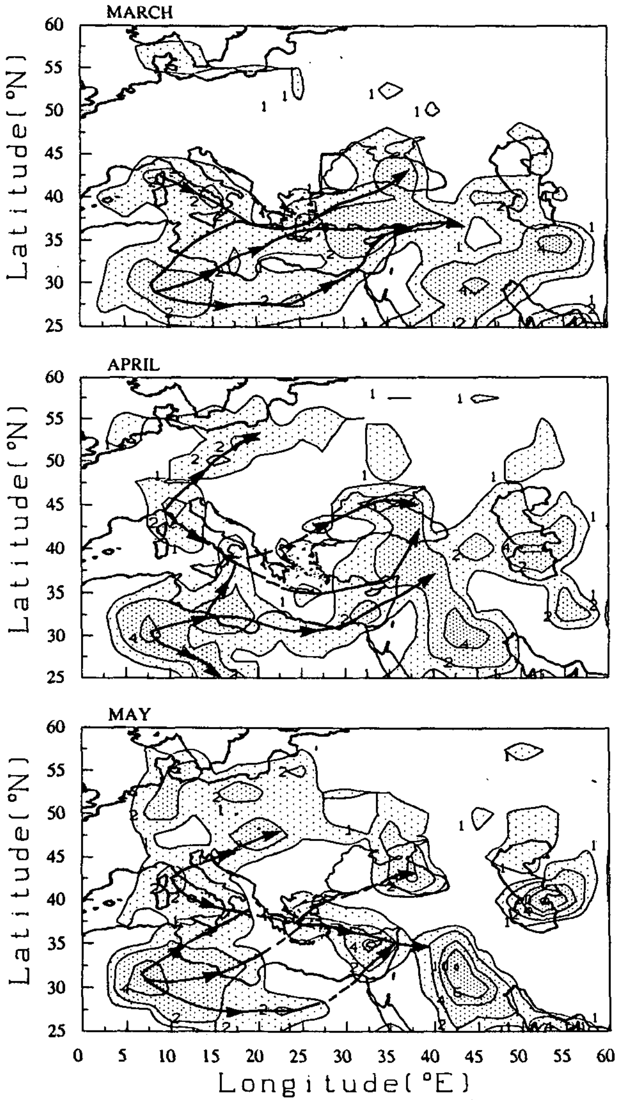

FIG. 2. As in Fig. 1, except for the spring months, March, April, and May.

and turn slightly to the northeast in April. In May they tend to move northeastward directly into the WM. One can notice at least three different tracks of these cyclones (see Alpert and Ziv 1989). The major route by which the cyclones leave the Mediterranean clearly moves from the EM in March to the WM in May. Similarly, the primary entrance region of the north African cyclones into the Mediterranean is in the EM in March and the WM during May.

In the summer months (June, July, and August; Fig. 3), the intermonthly variations are the smallest compared to the other seasons, nearly justifying the depiction of a seasonal picture for the summer; however, June can be clearly distinguished from July–August in the following two aspects. In June there are still a few tracks from WM to EM (particularly those reaching the Aegean Sea) and also in the area around the north African coast and central Mediterranean. In July–August the central and eastern Mediterranean as well as the north African center are dominated by the subtropical high. Any cyclones that form tend to be nonmigratory. In general they are shallow and probably related to thermal boundary-layer forcing. The only exit route for Mediterranean cyclones runs from the lee of the Alps to the northeast toward the Po Valley and the Hungarian basin (46°N, 20°E).

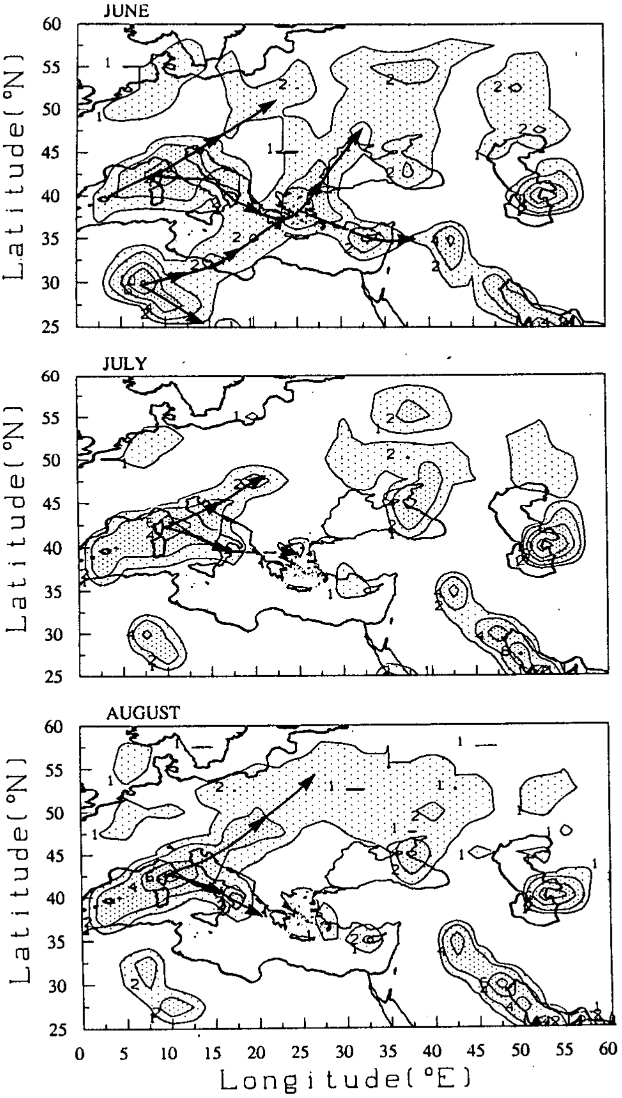

FIG. 3. As in Fig. 1, except for the summer months, June, July, and August.

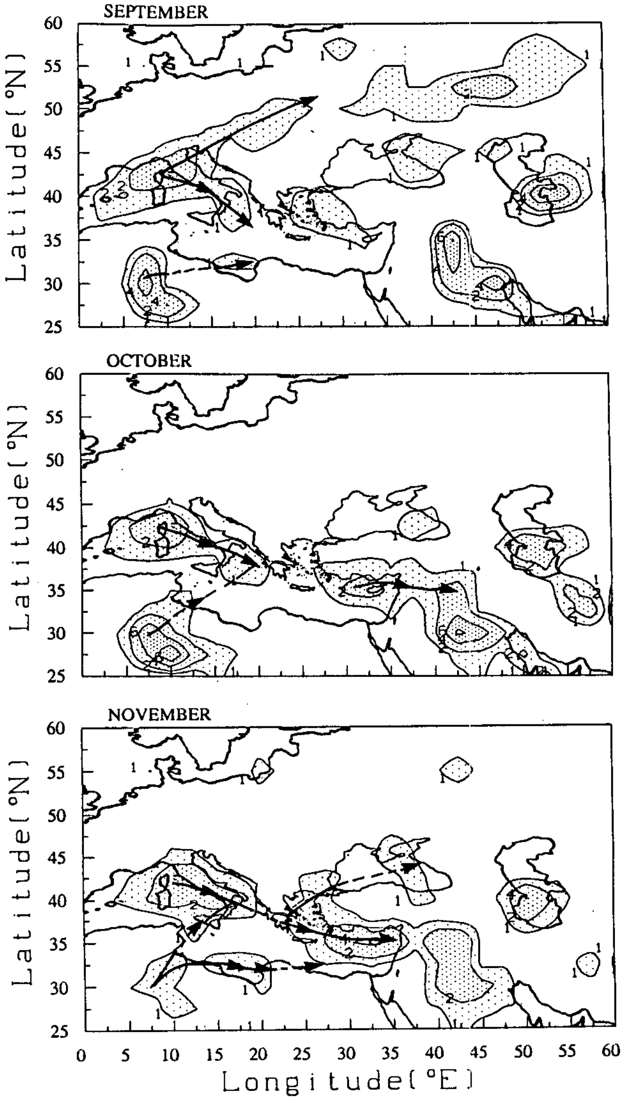

FIG. 4. As in Fig. 1, except for the autumn months, September, October, and November.

In September (Fig. 4), the influence of the subtropical high in the central and eastern Mediterranean begins to decrease. This is indicated by a slight increase in the number of tracks there as well as at the north African coast. Compared to September more tracks appear in the Mediterranean in October, but the picture still resembles the summer rather than the spring months, which is probably due to the relatively small thermal contrast between the land and sea. A track from the EM toward the east strengthens in October while the northeasterly track in the WM noted during the summer, especially in August, weakens or nearly disappears. The change towards winter is very pronounced in November as the density of maritime tracks increases significantly and as the northeastern route from the Aegean Sea forms.

To illustrate our main point Fig. 5 shows the composite of December, January, and February results from Fig. 1. Most pronounced in the winter mean is the dominance of the route along the northern section of the Mediterranean, Alpert (1989). Obviously the aforementioned unique features of each of the winter months cannot be distinguished in Fig. 5.

As monthly means may be more affected than seasonal ones by sampling problems it is of interest to compare the magnitudes of interannual and intermonthly variability. This is done for the grid point near Cyprus (35°N, 32.5°E) where we have calculated standard deviations of the cyclone track densities. The intermonthly variation (based on 12 months) σ_{IM} is 2.1, 2.2, 1.4, 1.8, and 1.7 for the years 1983–87, respectively, yielding an average intermonthly variability of 1.82. The interannual variation σ_{IA} is 0.6, 1.2, 2.1, 0.8, 2.3, 1.2, 1.2, 1.9, 0.6, 1.4, 2.3, and 0.8 for the months of January–December, respectively; thus, yielding an average interannual variability of 1.36. It is not unexpected that the average intermonthly variability through the year in the Mediterranean region is larger than the average interannual variability; i.e., $\bar{\sigma}_{IM} = 1.82 > \bar{\sigma}_{IA} = 1.36$. However, when the comparison is repeated for winter only (Dec–Feb) the variability values drop to similar magnitudes; i.e., $\bar{\sigma}_{IM}$ (winter only) $= 0.72 \leqslant \bar{\sigma}_{IA}$ (winter only) $= 0.85$. A similar magnitude is also obtained for the interseasonal variability $\sigma_{IS} = 0.87$. This result supports the suggestion that intermonthly variations are quite important. Obviously, though, the relatively short sampling period of five years used here needs to be increased significantly for a more conclusive result.

3. Summary

The tracks in the Mediterranean region exhibit significant intermonthly variations, particularly in the following, within seasonal transitions: December–January, April–May, and June–July. These intermonthly variations are lost in seasonal pictures. For example, the cyclonic route from the Aegean Sea to the Black Sea is most prominent in January but much weaker in December and February. The physical reason for the changes in the cyclonic routes from month to month may be found in the changing land–sea contrast in association with the complex topography of the region. This contrast affects the geographic area of maximum low-level baroclinicity yielding significant monthly variations as illustrated for instance by Alpert and Ziv (1989). The advantage of identifying specific monthly features is twofold. First, it allows better insight into the governing physical mechanisms. Second, higher temporal resolution of cyclonic routes leads to a better estimation of the variation of climatic variables like rainfall, pressure, etc. It is, therefore, suggested that

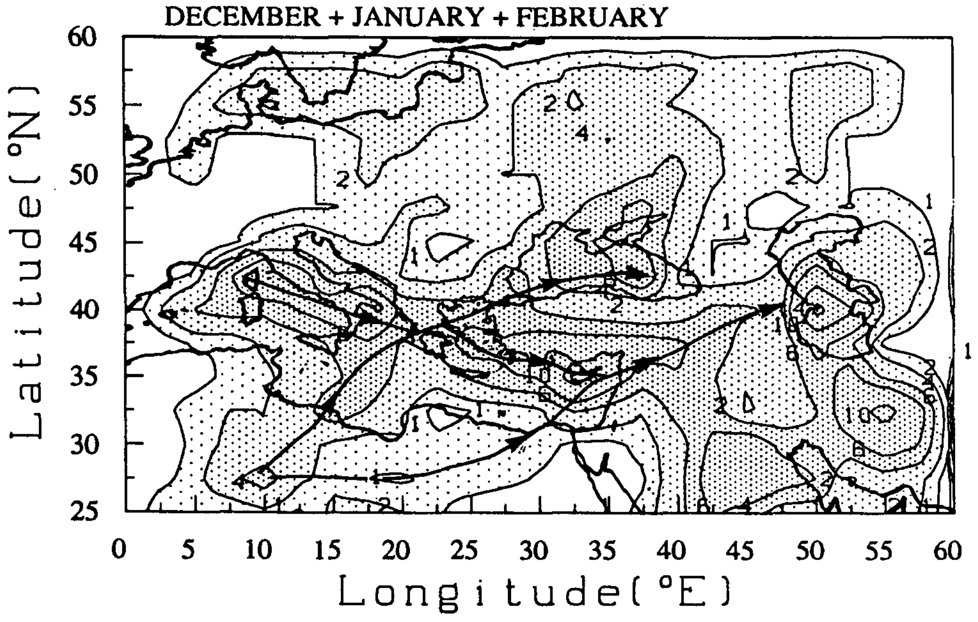

FIG. 5. Sum of the cyclonic track densities for winter months (Fig. 1), December, January, and February. Major routes as in Fig. 1.

faithful representation of climatic features over complex terrain regions like the Mediterranean needs higher temporal resolution than the seasonal one that has commonly been used.

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