NOTES AND CORRESPONDENCE

Comments on "Relationship between Cyclone Tracks, Anticyclone Tracks, and Baroclinic Waveguides"

PINHAS ALPERT

Department of Geophysics and Planetary Sciences, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, Israel

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Wallace et al. (1988; hereafter WLB) have suggested the construction of the baroclinic waveguide based upon three different methods. The first follows Blackmon et al. (1977)—along with a correction of the geopotential to a geopotential streamfunction—to associate the waveguide with regions of strong variability in the geopotential height field. Second, they identified waveguides with strong teleconnectivity, and third directed the waveguides along the phase propagation vectors as deduced from lag-correlation maps. Figure 1 (WLB, Fig. 19a) presents their 1000 mb waveguide picture for the high-frequency fluctuations in the Northern Hemisphere in which they have combined all three methods. The also discuss the similarities between these waveguides and the tracks of climatological mean cyclone and anticyclone tracks defined by Petterssen (1956) and others. In particular, WLB nicely illustrate (their Fig. 20) how in the western oceans the cyclones (anticyclones) track northeastward (southeastward) toward the centers of semipermanent oceanic low (subtropical high), while the corresponding waveguide is directed almost due eastward.

My concern here is another interesting map that Pettersen suggested for the specific purpose of representing the picture of "what may be called the traveling perturbations superimposed upon the basic circulation" (p. 275). This map was called high rate of alternation and defined as follows: "If C is the frequency of cyclones and A the frequency of anticyclones, C/A is the rate of alternation if A is greater than C; if C is greater than A we take the ratio A/C." Although WLB mentioned (in the Introduction on p. 439) Petterssen's (1956) suggestion of the importance of regions in which a high *rate of alternation* between cyclones and anticyclones is observed, they have *not* directly correlated their waveguide proposition and Petterssen's map for the winter rate of alternation (Fig. 2). For comparison WLB baroclinic waveguides from Fig. 1 were superimposed upon Petterssen's rate of alternation map in Fig. 2.

Wallace et al. (1988) correctly warn (p. 440) that Petterssen's storm track cannot be directly compared with the regions of maximum high-frequency variability as done by Blackmon et al. (1977) because of the sense of polarity, i.e., cyclones versus anticyclones. Hence, WLB follow by introducing the baroclinic waveguide as the more appropriate label for tracks of disturbances. However, Petterssen's definition for the rate of alternation is independent of any polarity and therefore, I suggest, could be directly compared with the baroclinic waveguides. Actually, as mentioned earlier Petterssen considered this map "the statistical pic-

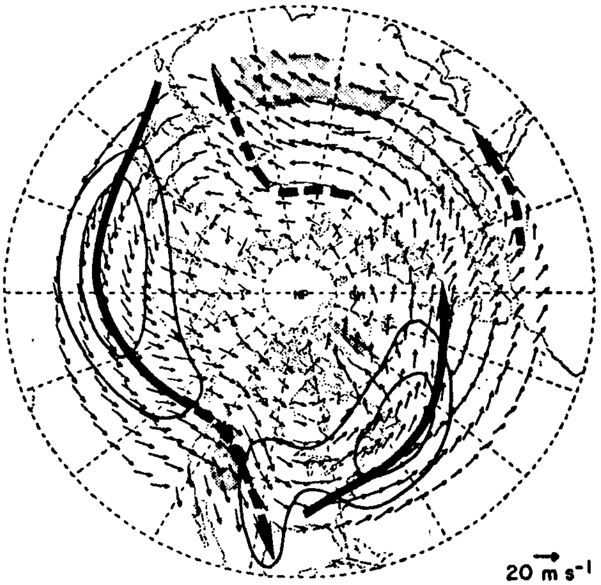

FIG. 1. Baroclinic waveguides at 1000 mb from WLB, Fig. 19a. The heavy arrows correspond to the axes of the bands of high teleconnectivity. The closed loops correspond to the 40 m (inner) and 50 m (outer) contours transcribed from the standard deviation of the high-pass filtered height field. The arrows are the phase propagation vectors from Fig. 8a in WLB. The dashed heavy arrows denote the less-pronounced portions of the baroclinic waveguides.

Corresponding author address: Dr. Pinhas Alpert, Dept. of Geophysics and Planetary Sciences, Tel Aviv University, Ramat Aviv, 69978 Tel Aviv, Israel.

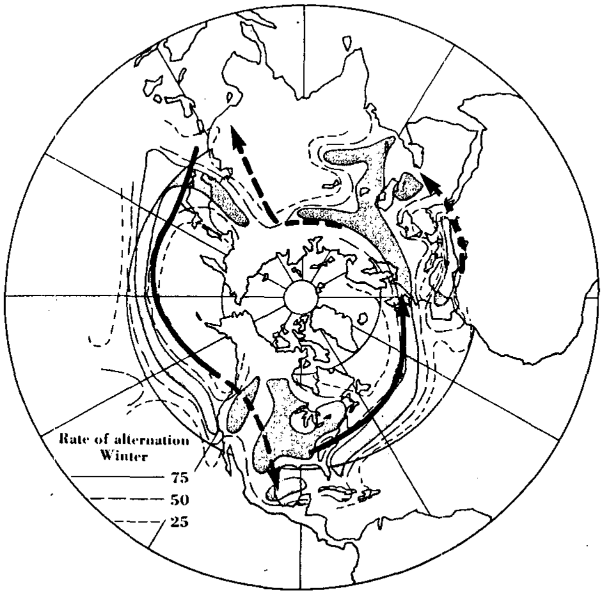

FIG. 2. Rate of alternation in winter from Petterssen (1956). For explanation, see text. The baroclinic waveguides from Fig. 1 are superimposed as heavy arrows.

ture of traveling perturbations", which could therefore be identified as the classical proposition for a "baroclinic waveguide."

The two waveguide pictures, Fig. 2, are very similar in many of their features. The Pacific waveguide along ~40° latitude starts southeast from the Asian continent then extends across the Pacific into North America and finally recurves southeastward toward the Gulf of Mexico. On the Atlantic side, the behavior is essentially the same in that the waveguide (WLB) or lane of high rate of alternation (Petterssen) both emanate from the East Coast of the United States and extend toward England. They also curve southward east of the Rocky Mountains and east of the Himalayas in both maps—although east of the Himalayas the curving in Petterssen's map is weaker and farther to the east. Another difference is the curving southeastward east of the Caspian Sea in Petterssen's map, which is not found in the WLB waveguide picture but does exist in the phase propagation vectors over Eastern Europe and towards the Black Sea (Fig. 1).

A more significant difference is the southern shift in the position of both oceanic waveguides in Petterssen's map. Of course, the data from which these maps were derived (1899–1939) were very sparse in the oceanic regions and much less reliable than that used by WLB (1964–83). But it should also be realized that Petterssen's definition following high rate of alternation is probably best related to the first method in which the baroclinic waveguides are associated; i.e., the strong variability in the geopotential height field. The relatively more northern position of the WLB baroclinic waveguides could also be the result of larger geopotential fluctuations on the cyclonic side of the waveguide position as compared to that on the anticyclonic side. In that case, Petterssen's rate of alternation seems more suitable for a baroclinic waveguide that is lacking the aforementioned polarity and in that sense may be closer to the "ideal waveguide" position.

An interesting feature in both maps is the Mediterranean waveguide, which in contrast to the aforementioned two larger scale waveguides is strongly associated with the local topography. In both maps the Mediterranean waveguide is clearly, as expected, to the south

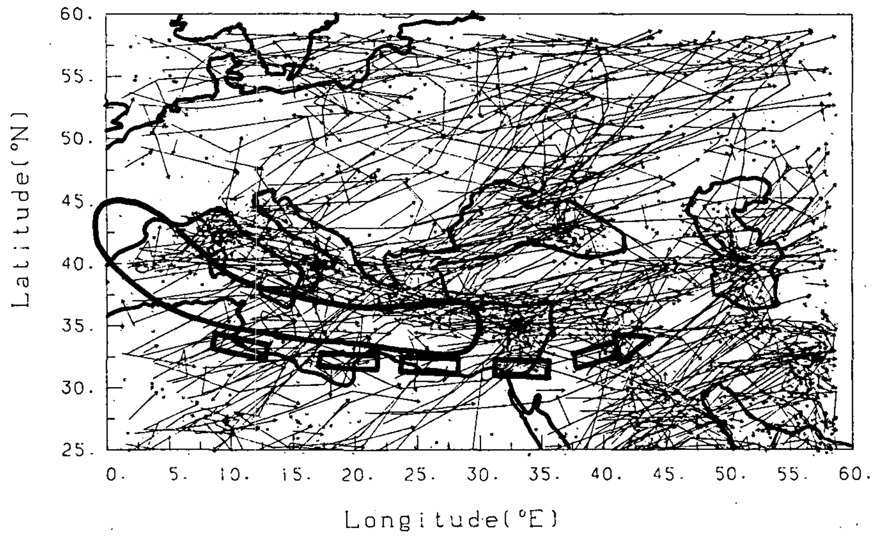

FIG 3. Cyclone tracks in the Mediterranean region for December–January–February during December 1982–December 1987. From Alpert et al. (1989). The Mediterranean waveguides from WLB, Fig. 1, and Petterssen, Fig. 2, are superimposed.

of the major cyclonic tracks (cf. Fig. 3). The cyclone tracks follow the northern border of the Mediterranean closely and are strongly associated with the lee cyclogenesis effects and the sea–land contrast (e.g., see Reiter 1975). The WLB baroclinic waveguide is much farther to the south. It is closer to the North African coast and is associated with the region of high teleconnectivity along that region (see WLB, their Fig. 6a). In contrast, the Mediterranean high rate of alternation, Fig. 2, is found somewhere along the center of the sea but fairly close and shifted to the north of the Mediterranean WLB guide. Again, the sparsity of data above the Mediterranean and the North African coast, particularly in Petterssen's study, could only partly explain these differences.

In summary, the purpose of this note is to point to the very close relationship between WLB *baroclinic waveguides* and Petterssen's *high rate of alternation regions* and suggest the latter to be an earlier version of the baroclinic waveguide.

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