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ON THE RELATIONSHIP BETWEEN TROPOPAUSE AND SUBTROPICAL JET STREAM IN WINTER AT 140°E

by

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Abstract

Some vertical cross-sections have been analyzed along the longitude 140°E to study the structure of the tropopause with special attention to conditions in the vicinity of the subtropical front in January 1958. The mean height of the tropopause has been computed and a model of the mean tropopause structure is presented. The core of the westerly subtropical jet stream at 35°N is located at about 200 mb.

1. *Observations*

The data for this study have been collected from the microcards of the IGY for January 1958. For the cross-section along longitude 140°E the following aerological stations have been used: 91115 (Iwo Jima), 47963 (Torishima), 47678 (Hachijojima/Omure), 47646 (Tateno), 47582 (Akita) and 47401 (Wakkanai). In addition, the following stations have been selected for the particular purpose to study the structure of the tropopause: 32061 (Aleksandrovsk/Sahalinskij), 31168 (Ajan), 24688 (Omjjakon), 91217 (Taguac, Guam, Mariana Is.) and 91412 (Yap, Caroline Is.).

2. *Principle of analysis*

Special attention has been drawn to the wind shear when analyzing the frontal structure. The analysis is thus different from that of Mohri

[5] and of NEWTON and PERSSON [6] because the tropopause does not follow the front but runs along the region of the maximal wind shear. Reference in this respect is made to the papers of BERGGREN [1], PALMÉN and NEWTON [7] and VUORELA [9].

The analysis of the tropopause has been carried out by following a certain isentropic level. However, certain variation of potential temperature along the principal tropopauses was permitted. An exception forms the uppermost tropopause, here called for the second tropopause, which does not follow the same rule. It is also questionable whether it is quite correct to call it for a second tropopause since this actually is

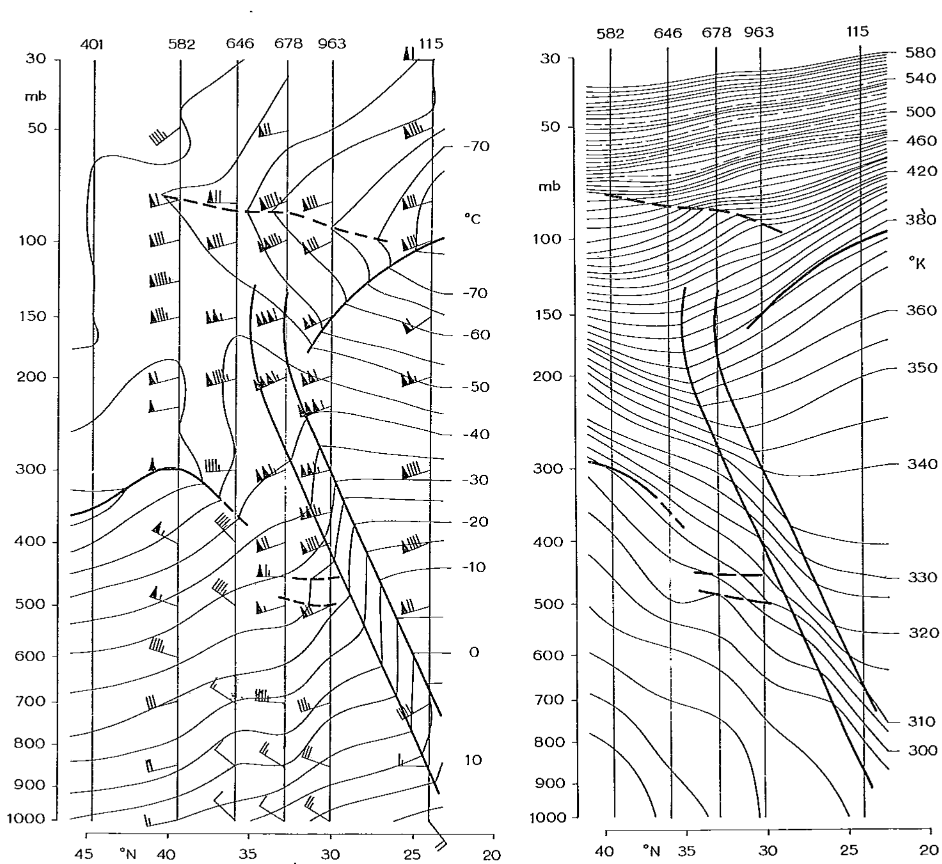

Fig. 1. Cross-sections along the longitude 140°E on Jan. 5, 1958 at 00 GMT. a) Vertical distribution of temperature and wind, b) Vertical distribution of potential temperature.

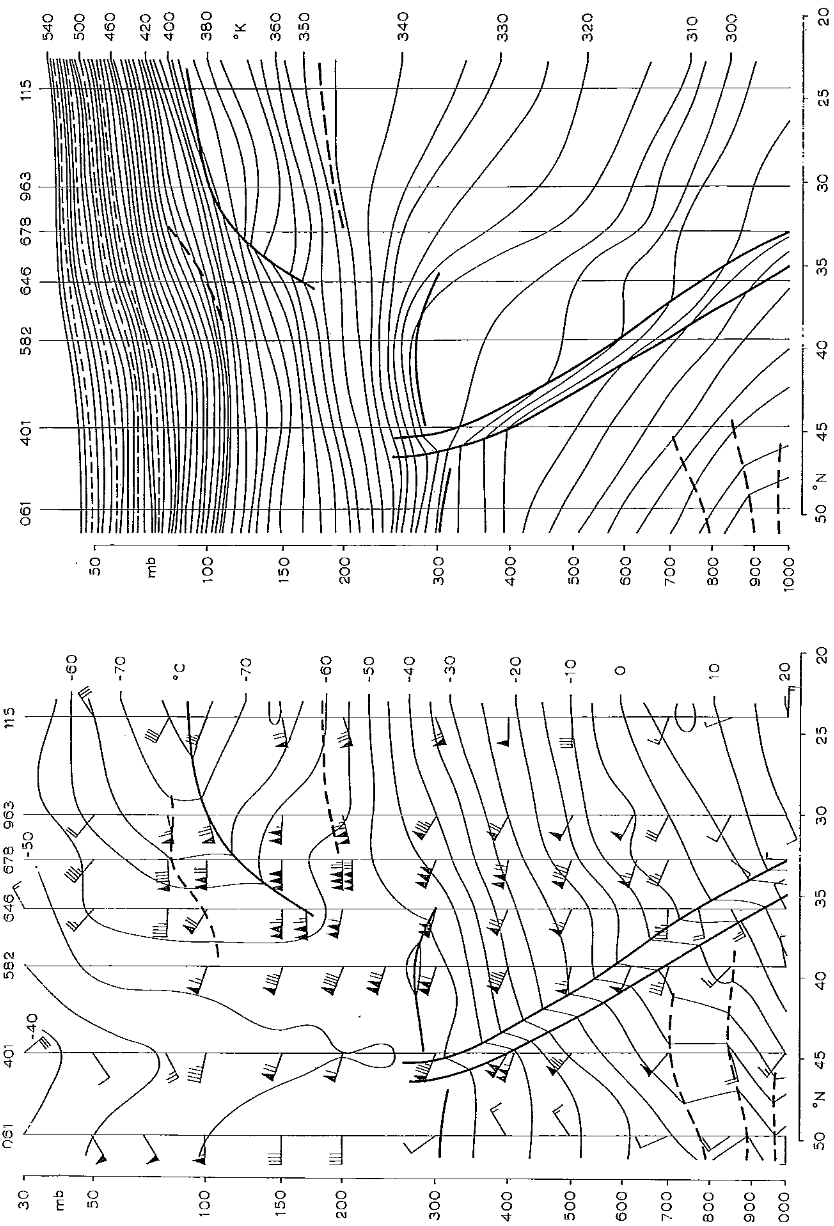

Fig. 2. Cross-sections on Jan. 12 at 00 GMT.

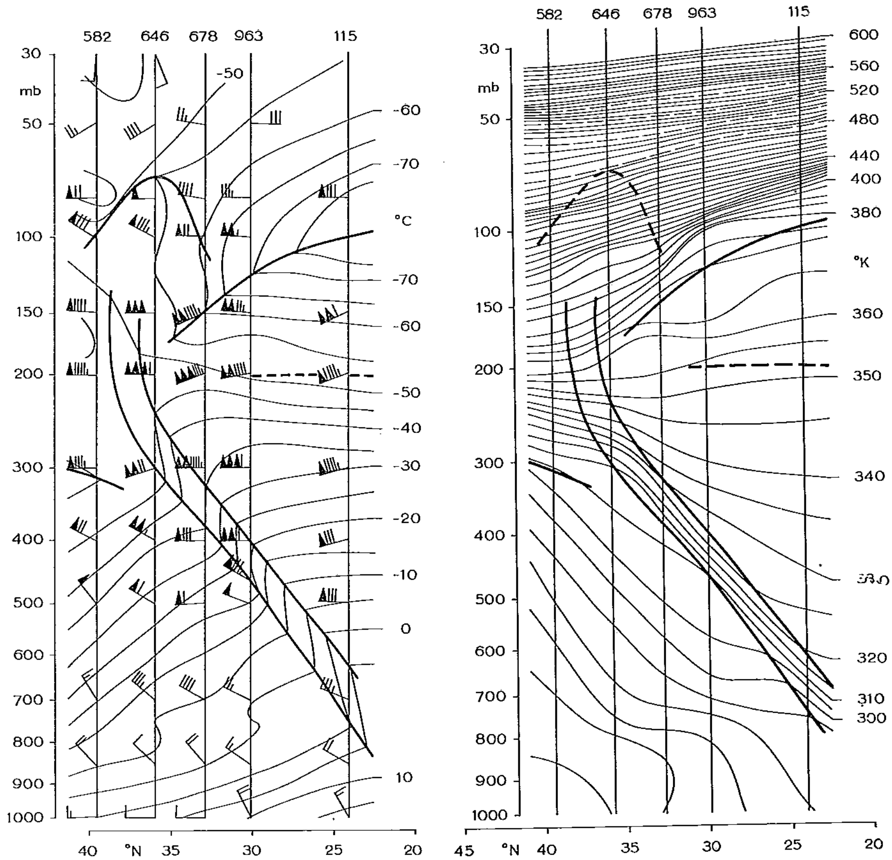

Fig. 3. Cross-sections on Jan. 19 at 00 GMT.

an upper limit of a more or less isothermal layer. The rule according to which the lapse rate is less than 2°C/km above the tropopause has been used to define the tropopause.

3. *Analysis of some typical situations*

The vertical cross-sections of January 5, 12, 19 and 25 at 00 GMT are given as examples in Figs. 1—4. Those of January 5, 19 and 25 are very clear conserning both the tropopause and the subtropical front whereas the situation on Jan. 12 is more confused in both respects.

The sounding of Iwo Jima (115) on Jan. 5 (Fig. 5) represents a typical conditions in tropics since there is a single tropopause of —77°C at 100

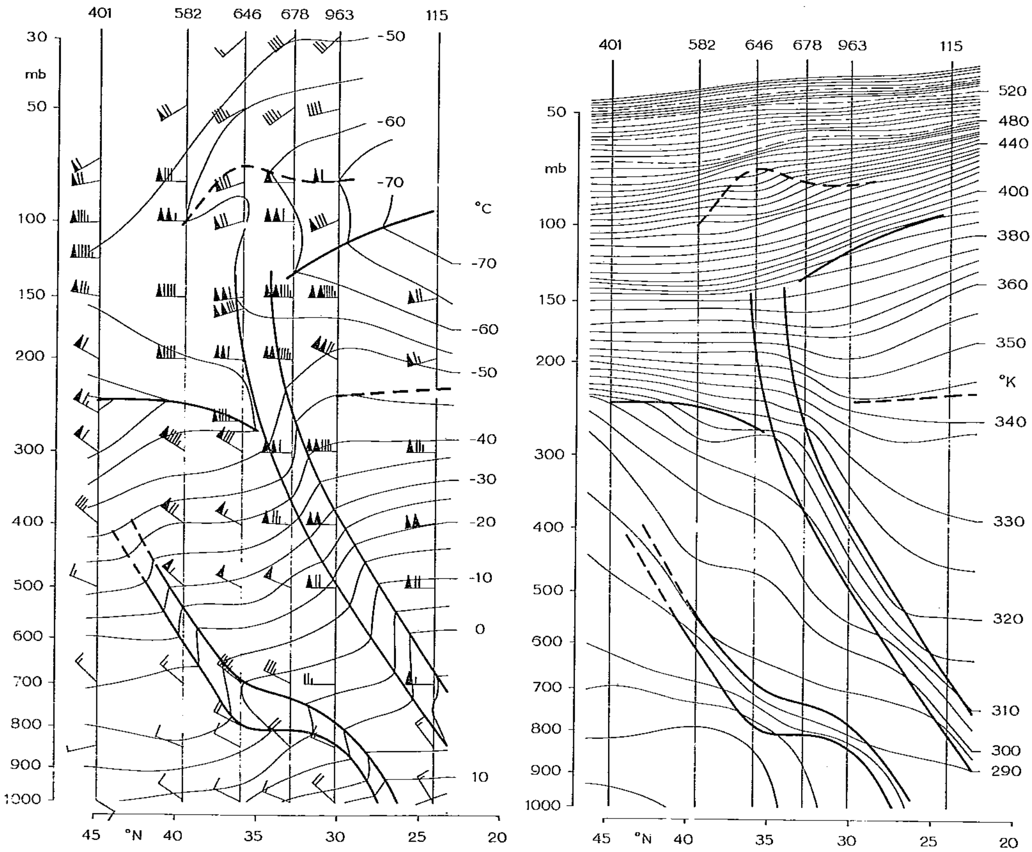

Fig. 4. Cross-sections on Jan. 25 at 00 GMT.

mb and the temperature at 500 mb is —7°C. Wakkanai (401), on the other hand, shows a polar characteristics with the tropopause at 360 mb, and a temperature of —37°C at 500 mb.

A distinct subtropical front appears between the latitudes 25° and 40°N. At Iwo Jima (115) it reaches the lower tropopause and a typical subtropical jet stream occurs at 200 mb. The soundings of stations 963, 646 and 582 show two tropopauses and the lower one of station 963 pictures an ordinary tropical tropopause as shown in Fig. 1.

The »upper tropopause» at 93 mb, on the other hand, can be defined as the upper limit of a more or less isothermal layer. It joins the upper tropopause of the stations 678, 646 and 582. This tropopause, however,

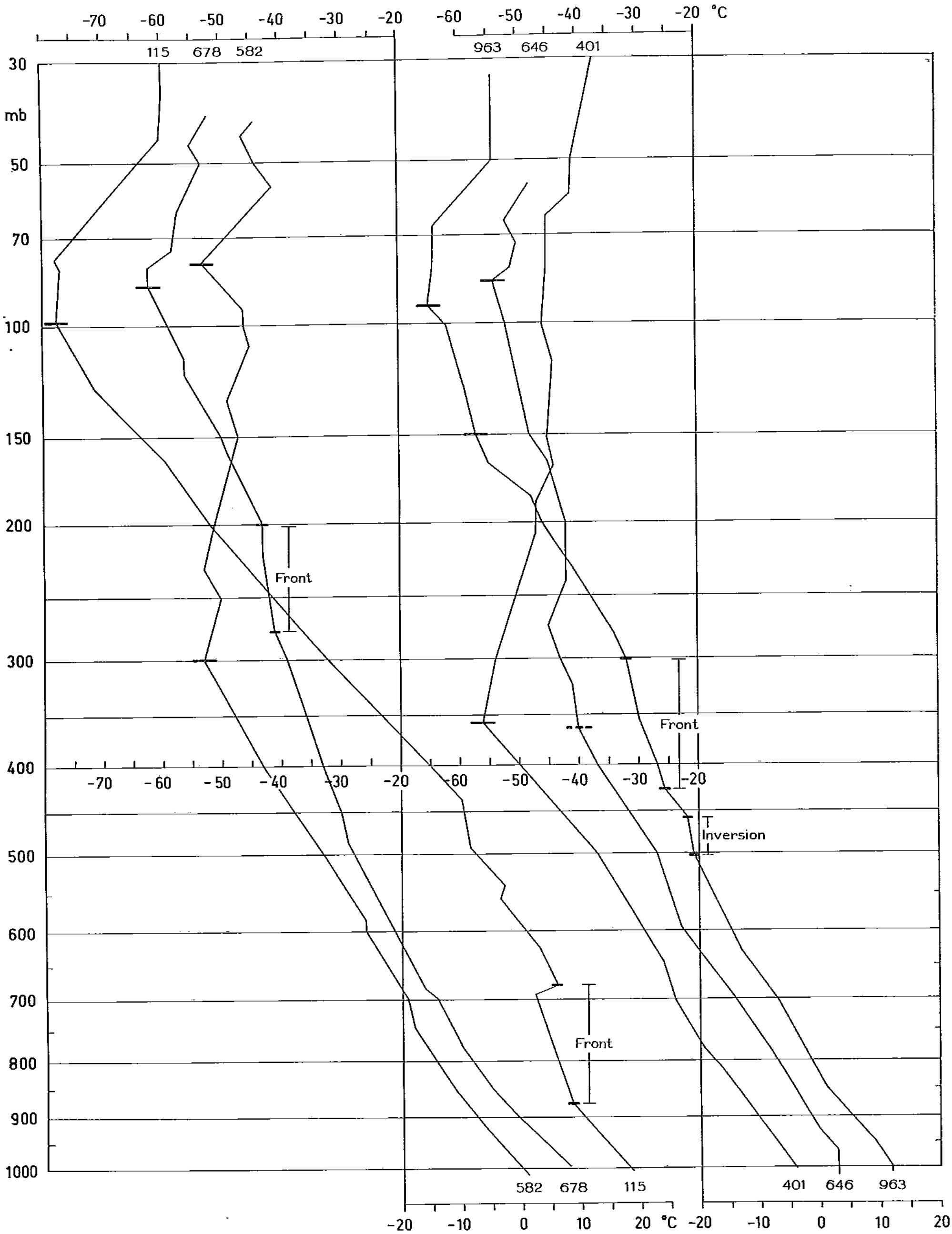

Fig. 5. Soundings on Jan. 5 at 00 GMT. Location of the tropopause is marked with a heavy horizontal strip.

does not satisfy the definition of an ordinary tropopause as a boundary of quasi-constant potential temperature. The cross-sections of Jan. 19 (Fig. 3) and Jan. 25 (Fig. 4) are of similar type as that of Jan. 5. A distinct subtropical front with the jet stream and a downwards bending of the tropical tropopause in the vicinity of the subtropical front are the characteristic features and the second tropopause is also discernible. Again, it does not join the tropical tropopause but is verified as a separate boundary layer above the subtropical front.

A common feature of the cross-sections of Jan. 5 (Fig. 1) and Jan. 19 (Fig. 3) is the absence of a polar front. In these cases the polar and subtropical fronts obviously are merged and the wind speed within the jet stream reaches very extreme values. The existence of a strong barolinic zone just below the subtropical front could possibly be interpreted as a remnant of the polar front. In the cross-section of Jan. 25 (Fig. 4) we can detect the polar front in the lower part of the troposphere.

The situation on Jan. 12 (Fig. 2) is an example of a case with a distinct polar front and an indistinct subtropical front. The latter of these does exist only as a strong barolinic region below the subtropical jet. A separate jet is also discernible in connection with the polar front. The case on Jan. 12 is more analogous with those appearing frequently in other longitudinal sectors of the world, as described *e.g.* by DEFANT and TABA [2].

A common feature in all the cross-sections is the occurrence of a secondary (lower) tropical tropopause at a height of about 200 mb in the tropical regions. It forms a boundary between the lower troposphere and the more stable upper troposphere. This type of stratification is characteristic of the average conditions in the tropics (Fig. 8).

4. *The jet stream*

In Fig. 6 we see the mean distribution of the wind speed in January 1958 at 00 GMT. The core of the westerly jet stream in lat. 35°N is situated at about 200 mb. The mean maximal wind speed is about 135 knots, in accordance with an earlier result of MOHRI [3] for the winter season Dec. 1950 — Feb. 1951. On the other hand, the mean value of the maximum wind speed is 162.5 knots at a mean height of 222 mb, if we take in account the highest wind velocity of every day, irrespective of the sounding station and the height. The absolute maximum is 220 knots at 208 mb, observed at Tateno on Jan. 10 at 00 GMT.

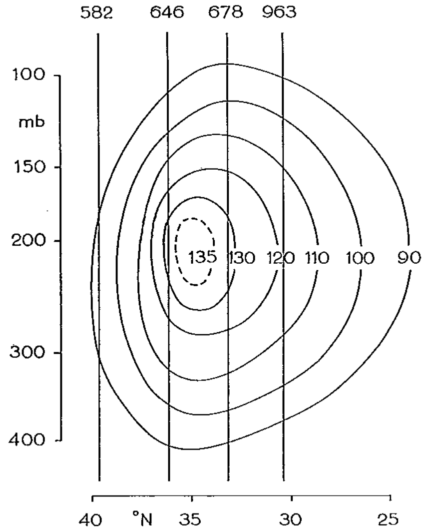

Fig. 6. Mean distribution of the wind speed, in knots, near to the core of the westerly jet stream in the region studied, in January 1958.

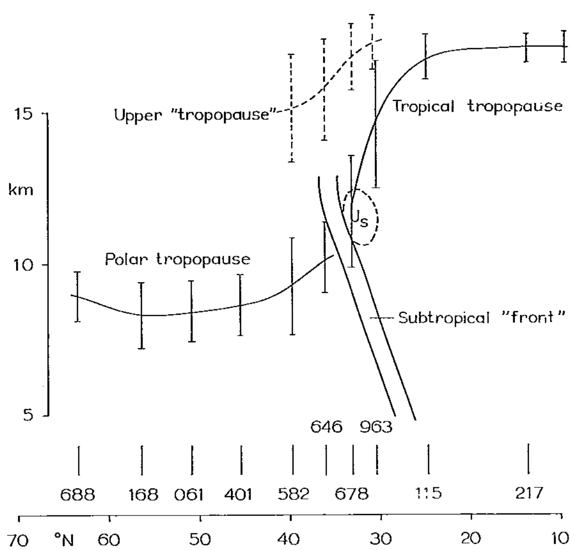

Fig. 7. Scheme of mean positions of the tropopauses and subtropical front in January 1958, based on the data of Table 1. Vertical strokes indicate the standard deviation of the tropopause height.

5. *A mean model of the atmospheric structure*

In Table 1 the mean values of the tropopause heights and their standard deviations along the meridian are presented. The mean heights of the tropopauses in Fig. 7 have been drawn on the basis of these values. The average position of the subtropical front, which intersects the tropopause at about 35°N, is also depicted. The standard deviation of the tropopause height is illustrated with vertical columns in the same figure.

The standard deviations are quite small at lower latitudes, but large in the vicinity of the mean position of the subtropical jet core. This is a consequence of the variation in latitude of the jet core and probably also of the velocity variations in the same core. The location of the subtropical front, or baroclinic layer, however, is quite well established. The standard deviations of the polar tropopause are of the order of one kilometer during the period under study. The dotted line in Fig. 7 shows the position of the uppermost tropopause, and the deviation of that is rather large. The location of this region of lowest temperature is thus very changeable, which also can be seen from the preceding figures.

For the interpretation of the polar tropopause and its standard deviations it should be kept in mind that only one front, the subtropical front, has been considered in this scheme. In some synoptic situations two fronts, or hyperbaroclinic layers, can easily be recognized. This occurs when the polar front is situated for northward from the subtropical front. In such cases (*e.g.* Fig. 2) the tropopause structure has the charact-

Table 1. The structure of the tropopause height. Φ (gpm) is the mean height of the tropopause, δ is the standard deviation and N the number of observations.

Station	Φ	δ	N	Φ	δ	N
24 688	8889	826	55			
31 168	8269	1124	60			
32 061	8376	1032	62			
47 401	8572	1078	62			
582	9202	1615	61	15071	1821	32
646	10125	1254	59	15722	1733	36
789	11543	1929	53	16787	1086	45
963	14573	2060	60	17240	961	38
91 115	16714	796	58			
217	17031	510	60			
413	17070	562	22			

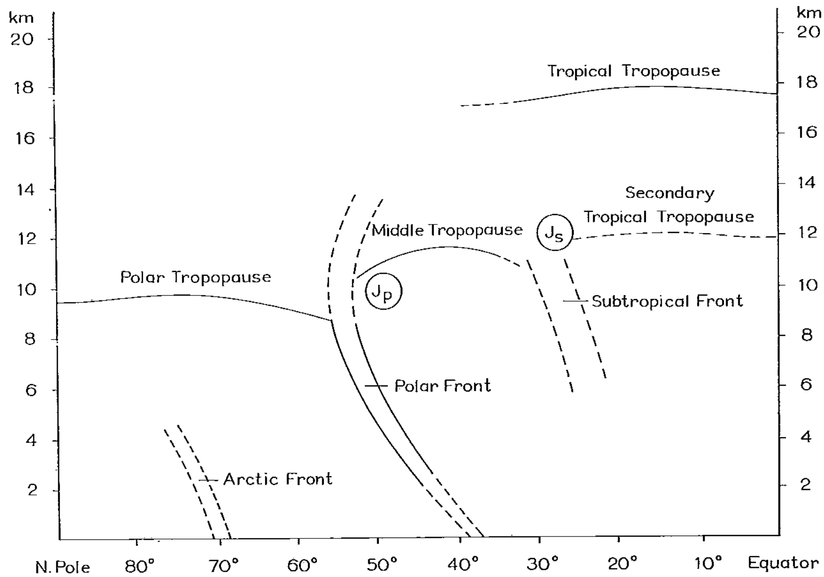

Fig. 8. Sketch of principal features of the tropopauses, frontal zones and jet streams on the Northern Hemisphere according to NEWTON and PERSSON [6], modified by PALMÉN and NEWTON.

eristics of a commonly accepted concept, precented schematically in Fig. 8.

The scheme in Fig. 7 illustrates conditions in a particular winter month (January 1958). This month represents predominance of cases in which the polar and subtropical fronts are merged. The upward bending of the southern part of the polar tropopause might be caused by the frequent presence of a »middle-latitude tropopause».

6. *Conclusions*

The study shows that the tropopause structure at the longitude 140°E in the vicinity of the subtropical jet is quite different from the average structure in other longitudinal regions with much more moderate wind velocities.

This is obviously related to the extreme wind values of the westerly jet in the region of Japan, where the subtropical and polar jets usually join. Northward from the jet core the height of the polar tropopause at first decreases somewhat, then increases again further polewards from around lat. 55°N. The height of the tropopause in the arctic region during this period is 10.13 ± 0.98 gpkm (HELIMÄKI [3]). A similar value has been found to present a common feature of the tropopause distribution in the Southern Hemisphere according to earlier studies [8].

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