The Stratification of the Atmosphere¹ (I)

H. Flohn² and R. Penndorf³

Abstract

A suitable nomenclature for atmospheric strata as well as a clear definition of the boundaries is proposed. The necessity of such a new classification is stressed. The atmosphere is divided into an inner and an outer atmosphere; from the latter particles may escape. The inner atmosphere is divided into three spheres—troposphere, stratosphere, and ionosphere—with each sphere in turn being subdivided into 3 or 4 layers. The new classification is based upon the thermal structure of the atmosphere. Boundaries of each layer are fixed by a sudden change of lapse rate.

The bottom layer, the ground layer, the advection layer, and the tropopause layer are subdivisions of the troposphere. The advantages gained by defining a separate tropopause layer as part of the troposphere are discussed in detail. Its upper boundary is assumed to be situated at 12 km over temperate latitudes. The stratosphere, consisting of an isothermal layer, a warm layer, and an upper mixing layer, extends from 12 to 80 km. The atmosphere between 80 and 800 km is occupied by the ionosphere, the subdivisions of which are the E-layer, the F-layer and the atomic layer. Above that height the exosphere exists.

1. The Necessity of a System of Classifying the Atmospheric Layers

A taxonomic system should be a tool of research. Its functions are twofold. Firstly it gives a common name to a concept so that semantic confusion may be avoided and secondly by its internal organization it structures the knowledge of an area of learning so that the relationships therein are clarified. As long as basic investigations in a particular field prevail neither a unique nor a formal system seems necessary. The present time, however, seems a good one for the presentation of such a system for the layers of the atmosphere. Such a system must be adopted on a very wide basis to avoid the unnecessary expenditure of energy in discussions which are purely nominal. The need for a clear system of classification is especially great in closely allied sciences where conventional meteorological usage is not familiar.

An example will demonstrate this. During the recent years with the increase of radiosonde data available daily, the recognition has been growing that the upper layers are of importance for forecasting. Thus the expression "stratosphere" entered the synoptic weather service. Especially in continental Europe "stratospheric steering" has been used so frequently that a sound definition of the adjective "stratospheric" is necessary. The

¹This article is based essentially on our paper: "Die Stockwerke der Atmosphäre," Meteorol. Zeitschr., vol. 59: 1-7 (1942). However, it has been completely rewritten and changed to a very large extent. We will be pleased if it opens a discussion on this subject.

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increase of knowledge on the steering layers necessitates a clear and specific demarcation of its boundaries. Unnecessary controversies have arisen between several authors and schools because the same word has been used for different layers. To prevent a similar confusion and misunderstanding in the future, we propose a partly new nomenclature for definite strata. In doing this we also hope to contribute toward a uniform terminology. Standardization of nomenclature seems urgently necessary.

Teisserenc de Bort divided the atmosphere into two layers, the troposphere and the stratosphere, based upon the simple thermal structure of the atmosphere known at that time. Later on Sir Napier Shaw introduced the term tropopause for the boundary between these two layers. During the past 20 years this classification proved to be too simple. More and more subdivisions were proposed. In German publications, e.g., the expressions “high troposphere” (Hochtroposphäre) and “substratosphere” were used. Several authors rather complicated the understanding of their ideas by using the notation “high troposphere” for the lower layer of the stratosphere too, whereas others applied the notation substratosphere for the upper troposphere. Furthermore the ionosphere was regarded as part of the stratosphere. Such varying nomenclature necessarily leads to seeming contradictions.

The expression “boundary of the stratosphere” is ambiguous. Two boundaries exist, an upper and a lower one. Up to the present only the lower boundary has been important for forecasting purposes. But in this era of rockets the upper boundary will undoubtedly be of importance too.

2. Classification of the Atmosphere

The foregoing was in mind in proposing a new classification of atmospheric layers. Based upon the best available knowledge of the thermal structure of the atmosphere, the scheme given in Table 1 was constructed. Subdivisions of the atmosphere are based best upon the lapse rate \( \gamma = -dT/\partial z \) (C°/100 m) because it characterized the meteorological properties of a layer in the simplest way (e.g., mixing, separation, convection, etc.). Boundaries of a layer are easily fixed by its change of sign or by a sudden change in its absolute value.

Thus our definitions are based upon a characteristic vertical temperature distribution discussed by one of the authors ([1], Fig. 10). It should be emphasized, however, that this curve is only valid for temperate latitudes. Above polar regions the temperature of the upper layers may be different.

In view of the fact that stratification occurs in the earth and atmosphere, i.e., the horizontal extension of a uniform property is greater than the vertical extension, it will always be sensible to use fixed strata as a guide to describe processes in the atmosphere. However, it is very frequently only a quasi-horizontal stratification, because additional accelerations occur within the atmosphere bending the boundaries of layers.

First of all the atmosphere is divided into an inner and an outer atmosphere. In the outer atmosphere the particles may escape from the gravitational or magnetic field of the earth whereas in the inner atmosphere this does not occur. In paragraph 6 more facts about the outer atmosphere will be given.

The inner atmosphere is subdivided into three spheres, and each sphere in turn into several layers. A layer is characterized by its uniform thermal structure: if several layers belong together according to their meteorological state and behaviour they form a sphere. This definition closely follows the common use. The word region is reserved for subdivision of a layer. In choosing the names for the layers and spheres we accepted the names already in use as far as possible. Table 1 shows the notations suggested and the meteorological characteristics.

3. The Troposphere

Microclimatology and spot climatology are mostly concerned with the study of the meteorological conditions adjacent to the earth’s surface, i.e., within the first two meters above the ground. It will be denoted bottom layer (bodenmahe Luftschicht) [2], [3]. Macroclimatology studies the conditions within the ground layer, that is up to about 2,000 meters [4]. Aerology [5] studies the climate of the free atmosphere, i.e., within the advection layer and the tropopause layer.

(a) The Bottom Layer

The conditions within the bottom layer are governed by physical constants of soil (absorption and emission of radiation), species of plants, their height, and formation. We shall not deal with this layer specifically (see [2]).

4 We neglect mountain stations because they do not represent the climate of the undisturbed atmosphere.

5 The term aerology is used as a subdivision of meteorology, the study of the free atmosphere throughout its vertical extent distinguished from studies confined to the layers adjacent to the earth’s surface (cf.: “Meteorological Glossary”).
### TABLE 1. NOTATION OF THE ATMOSPHERIC STRATA AND THEIR CHARACTERISTICS
(Figures valid for average conditions in 45°-55° N.)

<table>
<thead>
<tr>
<th>Layers</th>
<th>Exosphere</th>
<th>Ionosphere</th>
<th>Stratosphere</th>
<th>Troposphere</th>
<th>Bottom layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height in km approximately above 800</td>
<td>400-800</td>
<td>80-150</td>
<td>35-50</td>
<td>12-35</td>
<td>0.002-0.002</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Extreme values</td>
<td>2000?</td>
<td>1200?</td>
<td>+50 to +1000</td>
<td>-50 to -1000</td>
</tr>
<tr>
<td>Lapse rate in °C/100 m</td>
<td>2</td>
<td>+0.4</td>
<td>+0.4 to +1.0</td>
<td>-1.0 to -0.1</td>
<td>-10 to -3</td>
</tr>
<tr>
<td>Height in km approximately at upper boundary</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>1200?</td>
<td>+50 to +1000</td>
<td>+50 to +1000</td>
<td>-50 to -1000</td>
<td>-50 to -1000</td>
</tr>
<tr>
<td>Lapse rate in °C/100 m</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Layers</td>
<td>Atomic layer</td>
<td>F layer</td>
<td>Upper mixing layer</td>
<td>Isothermal layer</td>
<td>Advection layer</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ground layer</td>
</tr>
<tr>
<td>Lapse rate in °C/100 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Vertical gradient of Austausch coefficient \( \frac{dA}{dh} \)

<table>
<thead>
<tr>
<th>Vertical gradient of Austausch coefficient ( \frac{dA}{dh} )</th>
<th>Positive and negative</th>
<th>Negative constant</th>
<th>Positive and negative</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{dA}{dh} ) on positive</td>
<td>( \frac{dA}{dh} ) on negative</td>
<td>( \frac{dA}{dh} ) constant</td>
<td>( \frac{dA}{dh} ) positive and negative</td>
<td>( \frac{dA}{dh} ) negative</td>
</tr>
</tbody>
</table>

### (b) The Ground Layer

Besides thermal structure, variations of wind and Austausch with height are very helpful in subdividing the tropospheric layers. The immediate effect of surface friction is to reduce wind speed and to change wind direction. Surface friction also causes the dynamic constituents of Austausch, a term which will be used here in the sense of a turbulent mass exchange and which is generally accepted and well defined. Solar energy absorbed and transformed to heat in the soil leads to unstable lapse rates near the surface giving rise to updrafts which compose the convective constituent of Austausch. The *ground layer* is defined as a layer in which a noticeable influence of the surface (by friction) on wind occurs (i.e., up to the heights where the wind vector first equals the gradient wind) and in which the Austausch coefficient \( A \) undergoes characteristic changes. The upper boundary which extends up to 1 or 2 km in all climates is to a large extent determined by an inversion. Variations will be discussed at the end of this paragraph. The ground layer is more or less identical with Lettau's "planetary boundary layer". Aerological investigations have recently clarified some of its behaviour other than the already thoroughly studied influence of friction and Austausch. It seems necessary to subdivide this ground layer into two regions, a *bottom frictional region* and an *upper frictional region*. In the bottom frictional region \( A \) increases with height, reaching a maximum. The height and value of \( A_{\text{max}} \) depends on \( A_0 \), the roughness of the earth's surface, and the latitude, with the height ranging from 2 to about 100 m. The upper frictional region is characterized by a decrease in \( A \). This subdivision, fully discussed by Lettau, is especially important in regard to the explanation of variation of wind vector with height. Its upper boundary is defined by the lowest height where gradient wind and actual wind are practically equal. That occurs at about 1,000-1,500 m over continental Europe and U. S. A. Over oceans it will be at lower heights than over continents, and over polar regions as low as 400-600 m (Schneider-Carius). The deeper the bottom frictional region, the thicker is the upper one. If the convective constituent of \( A \) becomes large this conception of a bottom and an upper frictional region breaks down.

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6 Schneider-Carius [4] proposed this name or alternatively the Greek term *peplos*. Since we denote only spheres with Greek names but not layers it shall not be used here.
In the ground layer the temperature normally decreases with height (but there may be at times a negative lapse rate, as during the night or over Arctic regions) whereas the relative humidity increases with height. In the bottom frictional region normally clouds are missing; however, if $A$ becomes very small (and other conditions are favorable) fog or haze may form. The upper frictional region is frequently filled with haze where these two effects (increasing humidity and low $A$) combine. Under the upper boundary of the ground layer turbulence clouds (fractocumulus or fractostratus) may form. Convective cloud-forms, caused by high values of the convective constituent of $A$, have a pronounced daily period with a maximum in afternoon. The Peplopause acts as a blocking surface to air coming from above (e.g., the trade inversion; subsidence inversions in anticyclones).

(c) The Advection Layer

In this layer horizontal motions exceed vertical ones by a factor of 100–10,000. The term advection layer is preferred [4] since advection is far larger than convection. In 1942, we suggested the term “convection layer” or “cloud layer” but the new term proposed seems more appropriate. However, it is impossible to subdivide it into regions at this time without further aerological investigations. In this layer stratified clouds prevail and distinct cloud layers occur, as shown by many statistical and aerological studies. Subsidence and lifting change the lapse rate in this layer and give rise to the “weather.” In this layer the wind regularly increases with height. Thus the overrunning of warm air first occurs here announcing the arrival of a warm front. Overrunning cold air (voreanlde Kaltluft) frequently occurs in this layer causing unstable conditions. Subsidence must approach zero near the ground and therefore its effects on the ground layer are normally expressed only indirectly as a modification of surface air mass properties through mixing and cross-isobar flow, greater radiation, etc.

(d) The Tropopause Layer

(1) Earlier classifications.—Whereas the lower boundary of the troposphere, given by the solid or fluid surface of the earth, is clearly defined, different definitions of its upper boundary exist. Many textbooks state simply that the tropopause separates the troposphere from the stratosphere. Since the installation of a world-wide network of radiosonde stations in daily operation for about the last 15 years, stratospheric conditions have been thoroughly studied. They have shown that this conception of the tropopause is unsatisfactory. In earlier years it had been already known that the tropopause grew higher and colder as one proceeded from the pole towards the equator. Having that in mind, J. Bjerknes in 1932 reduced the explanation of day to day and seasonal variations in height of the tropopause to pure kinematic effects of meridional horizontal displacements of tropospheric air masses. Later on, however, cases were recorded in which the tropopause over middle Europe was much lower than the corresponding mean value over the polar regions. Studying synoptick tropopause “waves” more thoroughly, Palmén [10] came to the conclusion that vertical air motions contribute to its variations. The height of the tropopause changes nearly twice as much as calculated from the horizontal displacement of air particles. (In these calculations changes of height of isentropic surfaces have been used.) This discrepancy may be explained by assuming processes other than adiabatic. Palmén mentioned radiative cooling as such a process. But he believed it more probable that a new tropopause forms at another height and the older one dissolves. Furthermore he showed a new low tropopause forms in the later stage of cyclogenesis over deep cyclones. In a similar fashion the formation of a high tropopause has been observed over areas of quasi-stationary anticyclogenesis. Observations have shown numerous exceptions to the simple static picture of the tropopause as well as to the simple pattern proposed by J. Bjerknes. The tropopause is not a single solid surface as formerly suggested. It is frequently ill-defined, with multiple tropopauses often in evidence in sort of an overlapping leaf-like structure. In a new meridional cross-section through the atmosphere at 80°W, Hess [26] showed that the tropopause falls into a separate arctic and tropic tropopause. Even in the mean the discontinuity appears very distinct.

As early as 1909 and 1912 Schmauss [11] classified the tropopause into 4 types. Palmén [10] chose 3 similar types in 1933, neglecting Type III of Schmauss which—in the opinion of the authors—is mostly caused by instrumental errors due either to lag or to absorbed solar radiation. These classifications are essential to this consideration too, and the explanation of these types follows Palmén's idea of the influence of vertical motion upon the formation of the tropopause as mentioned above. For comparison the various types are grouped together in Table 2. In the classification of the authors the Normal
Type N prevails during a more or less stationary weather situation, the Lifting Type H characterizes warm air advection as well as warm-type anticyclogenesis, and the Subsidence Type S characterizes tropospheric cold air advection as well as the core of stationary (cold) lows. In these latter two types multiple tropopauses occur frequently. Thus, Schmauss Type I as well as Palmén Type I corresponds to the Normal Type N, Type II of both authors (with a strong inversion) to our Lifting Type H, and Type IV (Schmauss) or Type III (Palmén) (with a thick transition layer) to our subsidence types.

**Table 2. Tropopause Types**

<table>
<thead>
<tr>
<th>Flohn-Penndorf</th>
<th>Schmauss</th>
<th>Palmén</th>
<th>Characteristic temperature-height curve</th>
<th>Weather situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal type</td>
<td>N</td>
<td>I</td>
<td>I</td>
<td>stationary weather situation</td>
</tr>
<tr>
<td>Lifting type</td>
<td>H</td>
<td>II</td>
<td>II</td>
<td>warm air advection, warm air anticyclogenesis</td>
</tr>
<tr>
<td></td>
<td>III*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsidence type</td>
<td>S</td>
<td>IV</td>
<td>III</td>
<td>tropospheric cold air advection, core of stationary low</td>
</tr>
</tbody>
</table>

* In the opinion of the authors and Palmén this type does not exist.

(2) **Foliated structure and proposal of a tropopause layer.**—The presence of several inversions or isothermal strata needs careful consideration. It demonstrates that the tropopause consists of several dynamically unlike (unequal) surfaces, alternately appearing more or less pronounced. Thus the boundary between the tropopause and stratosphere becomes indistinct in middle latitudes. In such cases it is a matter of individual choice where the boundary between these two layers is placed.

This foliated structure is frequently observed at the boundary between subtropics and temperate latitudes at about 30–45°N. The upper apparent “equatorial” tropopause extends to 18–20 km or even higher, as examples from American stations, Italy and North Africa prove [12, 26]. During a voyage across the Atlantic from 50°N to 30°S radiosonde observations were carried out.

The cross-sections prepared by Vuorela [13] show this double polar and tropical tropopause on the poleward sides of the tropical anticyclones on both hemispheres. Contrary to conditions in tropical and temperate latitudes, in high latitudes, and especially under extremely cold conditions at the surface, the tropopause “disappears” entirely during the final months of the Antarctic winter (Little America III, 1940/41). There is more or less a steady decrease in lapse rate [14]. Under these conditions the tropopause should be classified as belonging to the Type S, indicating subsidence below 8 km.

These facts show that it is not always easy to define a tropopause even if single ascents are considered by pure hydrostatics, i.e., pressure-temperature relationship without regard to time. If there is but one sharp delineation between the tropospheric and stratospheric lapse rate the tropopause is clearly defined. $\gamma$ becomes either $> 0$ (inversion) or $= 0$ (isothermal stratum). However, several inversions or isothermal strata occur quite frequently instead of one. Sometimes neither an inversion nor an isothermal stratum occurs, but an irregular lapse rate. For these dubious cases no clear criterion for identifying the tropopause has been worked out. This is a source of confusion when figures for the height of the tropopause for different stations are compared. There exists a regulation in England which however does not satisfy all requirements. Criteria for the tropopause may be based, according to Court [14], on:

1. Level of minimum temperature (this is useless in the case of an isothermal stratum).
2. Level at which the lapse rate first begins to decrease.
3. Level at which the lapse rate first becomes less than some arbitrary value, such as $\gamma \equiv +0.2$.

The last criterion seems to be the best, and by adopting it, a distinct value will be obtained even for the Antarctic data mentioned above.

From careful consideration of these facts, it was concluded that it would be preferable not to try any new definition of the tropopause, but rather to define a separate layer in which the tropopause oscillates up and down, and in which multiple tropopauses occur. We proposed in 1942 the name *tropopause layer*. Byers in 1944 [15], dividing the atmosphere into layers, separates a specific tropopause layer too as “a zone of multiple tropopauses.” Since this proposal bears
some significance for meteorology, we shall discuss it in detail.

The troposphere ends at the lower limit of the isothermal stratum, and not at the inversion. Thus the upper boundary of the tropopause layer is well defined. This boundary is naturally situated above the lower limit of the inversion.

The lower boundary is harder to define. Disregarding the subsidence type where it agrees fairly well with a distinct change of the lapse rate, only conventional assumptions (e.g. 6 or 8 km, or perhaps the 300-mb level) would be satisfying. However, it seems more suitable to choose a gradual instead of a distinct boundary since the thickness may vary with latitude and season.

The values for the upper and lower boundaries of the tropopause layer for middle Europe are 8–13 km, in rare cases 5–15 km, for USA 10–18 km. These may be regarded as first approximations for the tropopause layer. In extreme cases the lower boundary descends to 4 km over a cold dome, e.g. Baltic (Riga), 24 January 1942, or Western Germany (Iserlohn), 19 February 1948, and over an anticyclonic warm-air advection it may ascend to 14 km or even higher. It may be mentioned in passing that the mean values are higher over subtropical and tropical regions, and lower over polar regions.

Flohn [16] drew maps for the mean height of the tropopause layer over the northern hemisphere in summer and winter. The mean values for each parallel deduced from these maps show a mean height of 16.5–17 km over the equator and 8–9 km over the pole. Its mean temperature ranges from −46° to −80°C in summer and from −57° to −83°C in winter.

Examples of soundings will be omitted because they may be found in standard meteorological text books. For various parts of the earth not too much is known so far concerning the tropopause layer, its structure, deepness, extreme values, or deviations from mean value as well as its role in atmospheric circulation and influence in tropospheric weather.

The water content decreases very rapidly in this layer too as shown by reliable measurements over Europe [27, 28] and U.S.A. [29]. The relative humidity stays below 10% in the upper part of this layer.

When we speak of a tropopause layer and bear in mind the frequent occurrence of multiple tropopauses, the classification of the tropopause as a Hadamard discontinuity loses its significance as do the theoretical conclusions drawn from this classification.

Now we shall discuss those facts which show this definition of the tropopause layer is advantageous, and which establish the influence of meteorological processes occurring in this layer on the lower troposphere.

(3) Advantages of the new proposal.—Some of the temperature changes in the tropopause layer may be attributed to the long wave radiation of atmospheric dust. Considering dust as a grey body Möller [17] calculated large temperature changes at the upper boundary of a tropospheric dust layer. Assuming a dust layer imbedded into the tropopause layer 1.25 km deep with a grey absorptivity of 20% the atmosphere is heated by 2°C/day below and cooled by ½°C/day above the upper boundary of the dust layer. The sharp decrease of both water vapor and dust in this layer will intensify the inversion. The lower temperature in this layer over the tropics has been attributed to the strong emission of CO₂ (Möller [18]).

The wind is mostly from the west, with velocity increasing and reaching a very pronounced maximum in the tropopause layer all over the globe. According to very valuable investigations by the Chicago Group a jet stream is imbedded in this layer too. It consists of a narrow belt of very strong wind, and a concentration of the isotherms within it. The high tropical tropopause inversion ends directly above it, the high tropical tropopause and the lower polar tropopause having no direct connection [26, 30, 31]. The jet stream is found meandering through the Westerlies all around the globe [32]; however, it is more pronounced on the east sides of the continents than on the west sides, where influence prevails. Moreover, its geographical position undergoes seasonal and day-to-day variations; there are often two jets present, one north of the other. The formation and maintenance of the jet stream is explained by Rossby [33] on the basis of large-scale horizontal mixing which results in a net flux of vorticity from high to low latitudes. This mixing is interrupted at a critical zone in middle latitudes, thus producing a sharp peak around 35°N. Namias [32] on the other hand thinks that it is caused by confluence of warm and cold air masses in the upper troposphere.

A mountain barrier causes internal waves with large amplitudes even in this layer, as theoretically investigated by Küttner [34], Colson [35] and Queney [36]. These waves are manifested by certain cloud forms and already have been used for gliding.

The Austausch A obviously is smaller here than below. Having determined the values for A be-

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tween 14 and 28 km, Lettau [19] assumed a linear decrease of $A$ between 8-14 km. This decrease is very important. The vertical distribution of ozone in the troposphere can be theoretically calculated, and is found to agree with the observations. A basic flow of ozone comes from the stratosphere down to the earth’s surface, where it is destroyed as proved by theoretical investigations. The distribution within the troposphere is largely due to Austausch. The strong increase of ozone concentration above the tropopause layer is caused by the sharp decrease in $A$ according to Lettau’s calculation [19]. The height of increase of ozone concentration is determined by the height at which the upper boundary of the tropopause layer occurs. The variations of this height with latitude depend on the variation of the tropopause layer with latitude. The direct measurements of vertical ozone distribution carried out by V-2 ascents confirm this fact [37, 38]. Duitsch [20] calculated $A$ for different latitudes and his data agree very well with those published by Lettau. E. Regener [21] stressed the relationship of ozone and turbulence by various examples.

The lapse rate in this layer largely depends on vertical motions. Junge [22] investigated the acceleration of sounding balloons. It decreased up to 8 km; however, an increase was recorded from that height all the way up till the bursting altitude at 15 km. The ascension rate of pilot balloons measured carefully in Germany (Lindenberg), as well as the experience concerning bumpiness during stratosphere flight, supports Junge’s result. This would mean that the turbulence increases in the tropopause layer. However his result is subject to criticism, because he assumed a close correlation between the acceleration of the balloons and the turbulence in the atmosphere. Fluctuations of temperature as observed during the flight of Explorer II [23] may cause static variations of buoyancy, and they in turn could result in an increase of acceleration of the balloons.

Tropopause waves traveling in this layer may tend to steer the course of weather phenomena in the lower troposphere (but not the large-scale pattern for long-range forecasting). The strong vertical motions, mentioned above in connection with Junge’s investigation, are regarded as one of the most important causes for the tropopause waves as well as for the temperature variations.

Several studies of interdiurnal pressure and temperature variations in Europe and USA [24] showed that a maximum of interdiurnal pressure change occurs near 8 km without regard to the signs of surface pressure and temperature changes. Pressure and density changes are largest above 8 km when the changes of sign are alike. A zone of density changes close to zero is found near 8 km. The temperature changes without regard to sign show maxima at 6 and near 10 km (maxima occurring at the surface are disregarded).

These results indicate these maxima occur in the tropopause layer. Up to now they have been assigned partly to the lower stratosphere and partly to the upper troposphere. This apparent controversy vanishes with the new definition of a tropopause layer. Compensation mainly resides in this layer. Within the tropopause and iso-thermal layers the atmosphere tries to compensate the pressure contrasts of the lower troposphere, the maximum contrast being reached at the tropopause. The term compensation means that a warm troposphere is coupled with a cold stratosphere and vice versa. Its importance to weather has been strongly emphasized by various papers of the “Frankfurt School.” The average compensation and especially the deviations from it are fully described by Scherhag [39], who demonstrates in many examples—using thickness charts—that the tropospheric temperature distribution is normally already compensated between 225 and 96 mb.

Studying processes in old cyclones and anticyclones under the aspect of the compensation between the lower troposphere and the tropopause layer, it is concluded that there exists a high layer where air is either flowing into the isobaric system or out (Thomas [25]), with strong vertical motions above and below this level. A similar conclusion is also drawn by Palmén and Nagler [31, Figure 16]. That means in the upper-air circulation there may be, in addition to the horizontal meridional advection effects, either a confluence or diffluence, depending on the position with respect to an upper trough or ridge. Furthermore, some authorities believe the processes causing this in-and-out pumping component of the upper-air circulation may originate in this layer [31].

For these various reasons it is advantageous for synoptic meteorology to separate this layer from the advection layer as well as from the isothermal layer. We classify it as part of the troposphere, because its behaviour, in regard to tropospheric weather, is presumably more closely connected with this sphere than with the strato-

\[ \text{(To be Concluded)} \]

\[ \text{Räthjen and Zistler use the term “Gegenläufigkeit.”} \]
References


Bulletin American Meteorological Society

Revision of the “Monthly Weather Review”

The *Monthly Weather Review* will be revised effective with the January 1950 issue. The climatological data tables which for many years have been published in the *Review* will hereafter appear in a new Weather Bureau publication, “Climatological Data—National Summary,” to be issued monthly.

Although it will no longer publish the climatological data tables, the *Monthly Weather Review*, as implied by its title, will continue to review the weather of the month. This review will consist of two monthly articles and the climatological Charts I-XI. The articles will (1) discuss the weather of the month and interpret the Charts in terms of the mean circulation pattern of the Northern Hemisphere, and (2) discuss an outstanding weather situation and interpret its meteorological features in terms of analyzed synoptic weather charts.

The removal of the climatological tables from the *Review* will permit it to carry more articles on meteorology than has been possible in recent years. As in the past, preference will be given to articles on synoptic and applied meteorology, but original contributions to all phases of the science are invited.


