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Meteorotropy and medical-meteorological forecasts

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Abstract. The meteorotropic reaction of the human organism is a function of different factors, such as the type and intensity of the effects of the physical environment as well as individual conditions like adaptive capacity and state of health. Many medical-meteorological studies show causal correlations between conditions in the lower atmosphere and reactions of the human organism, but also combined or synergistic effects of different weather situations, which can only be proved stochastically. These effects are described and the methodology of the investigations, as well as the results, critically discussed. Furthermore, application of the results in the areas of medical-meteorological consultation, with the goal of improving living conditions, is considered.
Key words. Influence of weather on human organism; complex of effects; biotropical weather situations; meteorotropy; medical meteorological consultation and forecast.

Introduction

The physical processes in the lower atmosphere are called weather in the short term or climate over a longer period of time. These processes are natural factors which influence the human organism. The resulting reactions are therefore mostly physiological, such as adaptation or acclimatization to changed weather situations or unaccustomed climatic conditions. The nature of the so-called meteorotropic reaction is a function of the intensity of the influencing factors, and of the exposure to them, as well as the individual's adaptive capability. The degree of exposure in turn depends upon behaviour, location and time. The biological influence of weather, also called biotropy, can be characterized variously as 'conditioning', 'stressful', or even as 'health-endangering'.
The task of medical-meteorological research is to consider the influence of weather on the human organism, in the so-called biosynoptical time scale. A further task is to estimate the contribution of the weather to the environmental conditions of the human being. In this sense biosynoptics, due to its use in the field of prevention, is a part of environmental medicine: for example, research results may be used in medical-meteorological consultations with the goal of improving living conditions, or in the optimization of therapeutic and prophylactic measures.

The complex systems in medicine-meteorology

The complex human being

With the exception of extreme conditions weather cannot cause diseases. It can, however, be a trigger for acute diseases or contribute to an aggravation of chronic problems, if the organism's adaptive ability cannot cope with the weather stimuli. People, therefore, react differently depending upon the meteorological conditions and the organic system affected. The reactions range from slight impairments of the general feeling of well-being to the triggering of death for seriously ill patients[31].
As with any stress the negative component is not of sole importance (disstress). On the contrary, changes in the atmosphere caused by weather can improve or train the adaptive ability of the organism (eustress). An appropriate weather-dependent behaviour requires that one exploits positive conditions, especially the chance to be outside, which our life-styles often neglect. In addition, an appropriate weather-dependent behaviour requires that we protect a sensitive or damaged organism from adaptive demands that are too strenuous.
Statistical studies have been used frequently, with varying success, to clarify the relationships between weather and the human being. Even if one has doubts about the quality of methodology of many studies, there are a large number of findings that have been reproduced independently, which can be considered reliable. The numerous difficulties associated with attempts to prove the effects of weather on the organism point to a very complicated problem. These attempts have also shown that the human organism as well as the atmosphere are complex systems of a high order. Clarifying relationships between these two systems is not a simple matter. That is why there have been various attempts to portray these complex relationships more clearly by constructing classification systems.
With respect to the human organism one can differentiate between three types of reaction depending upon the strength of the response to weather stimulus[4]:
- weather reaction: reaction, conditioned by weather, in the sense of a physiological adaptive process that is not viewed negatively;

- weather-prone: functional disturbances with impairment of the general well-being and symptoms such as headaches, sleep disturbances or physiological misperceptions that have no direct connection to a disease; and
- weather-sensitive: pathological symptoms where previous illnesses have occurred, such as chronic obstructive bronchitis or cardiac and circulatory diseases.

The boundaries between these three reaction levels are fluid and dependent upon the strength of the stimuli, the degree of damage to the organism, and a number of other factors.

The complex meteorological environment

In order to create a meaningful physically and physiologically relevant calssification of the numerous elements of the lower atmosphere, so-called complexes of effects were defined[26]. These effects allow a definite classification of the effecting variables and in addition establish causal relations for the reactions of the human organism. A complex correlation, however, can only be causally explained if the relationship between the individual components are known. The influence of weather is due to a multitude of individual meteorological elements, often closely related. They mutually affect one another or are collectively guided by another variable. To systematize the meteorological elements the well-known division into three complexes of effects is used. These are the complexes of thermal, of actinic and of air-quality effects.
The complex of thermal effects comprises all elements which determine the heat loss of the human being and thus directly influence thermo-regulation. These elements include air temperature, wind, humidity, direct and indirect shortwave solar radiation, long wave radiation of the atmosphere, clouds and of the surroundings of the human being.
Thermal discomfort is the decisive cause of meteoropathological disturbances. On the other hand the minimal influence of the outside thermal conditions on indoor conditions is repeatedly emphasized. Shielding, however, is never complete, and the transition to outdoors can lead to even greater demands on the organism. There are indications not only that thermal extremes lead to strain, but that extraordinary deviations from the seasonal norm can also contribute to the onset of a disease. Therefore, behaviour such as the time spent outdoors, clothing and heating habits may also play a decisive role[2,12,22].
Little is known about the complex of photoactinic effects (light, UV) in connection with meteoropathological disturbances. Since light, without doubt, plays a large role in human life there is a possibility that large weather-dependent changes in light conditions have a significant influence. Other possibilities include an effect of the circadian rhythms, so that proof may be considerably harder than with other complexes of effects.
The air-quality complex encompasses the natural components of the atmosphere as well as those present due to pollution. In connection with meteoropathological disturbances the effects of changing pollutant levels due to weather changes are of interest. These fluctuations occur not only in winter with minimal air exchange, but also in summer when the development of photochemical smog is enhanced by radiation. The partial pressure of oxygen, which changes with air pressure, is important for the organism. Weather-induced changes, however, cannot be assumed since considerably larger changes (for example, in an aircraft or on high mountains) only lead to complaints when serious damage to the heart or circulatory system already exist.
We can assume that these three complexes of effects consider all essential factors. Possible additional variables, such as those from electromagnetic waves, are not yet positively proven but cannot be discounted (see contribution of Reiter in this review). In correlating meteorological data with reactions of organisms, the assignment of elements of the atmosphere to different complexes has the disadvantage that the synergistic effect of elements, which belong to separate complexes, cannot be recognized. On the bioclimatic time scale, every complex of effects has an influence on the human being, and each complex can be used separately to evaluate a location bioclimatically. The relevance depends upon the season and the location. On the other hand, on the biosynoptic time scale (weather time scale), all complexes of effects contribute to the total accord of effects, interacting synergistically; the importance of the individual complexes may vary with time and location. Within the individual complexes the importance of single elements may vary in significance. This then leads to a decrease of causal relationship clearly evident on the climate time scale when viewed in the short term. The clarity of these relationships is further reduced by individual conditions and the variability of the human being which become more prominent in the short-term. This problem can be solved by the construction of a biosynoptically-orientated partitioning scheme, which allows varying constellations of the complexes of effects to be differentiated. This is done by classification of the basic dynamic processes or the resulting weather situations.
Through a correlation of differing weather classes with medical data or events, it is possible to consider all complexes of effects equally. It is also possible to recognize the significance of the individual effect-complexes for special medical fields.

Relevant medical-meteorological classification systems

During studies of the influence of weather on the human being in the past four decades a qualitative standardization of weather has proven useful. The Central

Medical-Meteorological Research Department of the German Weather Service (Zentrale Medizin-Meteorologische Forschungsstelle des Deutschen Wetterdienstes) in Freiburg developed a classification procedure that allows an objective analysis and forecast of all relevant weather phases in the temperate latitudes, in particular weather phases which have proven to be especially biotropic in a large number of statistical studies: for example, the back and the front sides of lows which contain warm advective air and cold advective air respectively. Vorticity and the so-called temperature-humidity-environment were used as objective parameters for the calculation of individual weather phases or classes. Vorticity is a variable that is used in general meteorological analysis and forecast models for the calculation of dynamic conditions in the lower atmosphere. It provides information about the intensity of pressure formations or their changes and the weather process associated with them.

A further differentiation of the classes resulting from this is achieved through the inclusion of the temperature-humidity environment in this procedure. The temperature-humidity environment is understood as the change of temperature and humidity in comparison to a previous meteorological period on a time scale for a weather segment (about 7 days). This is calculated as a deviation of temperature and humidity of the current day from a gliding weighted mean for the seven preceding days. Here the first day is weighted the most and the last day the least[16].

Thirteen classes can be distinguished by

1) using the value of absolute vorticity at the 850-hPa-level as a measure of the intensity of the meteorological situation at the beginning of a time period to be classified,
2) using the change of vertical distribution of vorticity as a dynamical parameter, or by

Table 1. Objective weather classification (Freiburg)

1	Anticyclone (centre) with good vertical mixing
2	Anticyclone (centre) without vertical mixing
3	Down slide motion at the edge of an anticyclone
4	Warm air advection in front of a cyclone
5	Warm sector
6	Centre of a cyclone
7	Cold air advection behind a cyclone
8	Region of trailing front
9	Easterly air flow (1: cyclonal, 2: anticyclonal)
10	Indifferent weather situation (no dynamic processes)
11	Cold high pressure system
12	Warm area of an anticyclone
13	High trough

3) the temperature-humidity environment.

These classes can be assigned to the synoptical areas in figure 1 and are meteorologically defined in table 1. The objective classification procedure allows a current analysis and a forecast of the weather with respect to biosynoptic aspects by employing the results of numerical weather analysis and forecasting. With the help of appropriate data banks a regionally differentiated and retrospective calculation of weather situations can be accomplished. These calculations then can be related to biological data. It is also possible to relate past results of medical-meteorological studies, obtained using different classification methods, to the new objective biosynoptic scheme. In this way the results are transformed onto a uniform weather classification scheme.

Methodology of medical-meteorological studies

Data collection

Medical-meteorological effect studies are based on statistical analyses of the relation between medical and meteorological time series. They are, therefore, longitudinal studies. They have all the problems associated

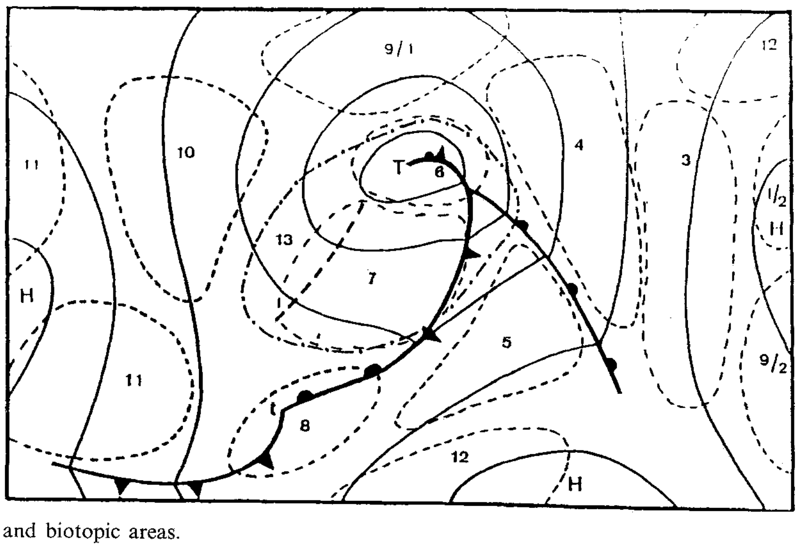

Figure 1. Ideal cyclone and biotopic areas.

with time series, resulting from the complicated structure of data series. The medical data possess a large variance which arises from a multitude of interference factors. Trends are frequently apparent, such as annual, weekly or daily rhythms. Social influences such as holidays or vacations have the effect of interference variables. It is therefore necessary to make a selection or a summarization of the data based on representative criteria.

Problems of regression analysis

The complicated structure of data series requires considerable care during relational analysis. Finding pseudo-correlations is a common problem which can make proving genuine correlations difficult. Much of the variation in data series is due to annual rhythms and circardian fluctuations. A correlation calculation with unadjusted data always includes portions of the correlation from all areas. The 'influence of weather', however, is only to be considered as that portion of the correlation which results from the interdiurnal changes. This effect becomes especially prominent in series which have a very similar annual rhythm. If one correlates a temperature series with a series of the daily frequency of cardiac infarctions a very close negative correlation results, even if no connection exists when viewed over a short time interval. This is due to the seasonal similarity of the time series. Here we are dealing with a so-called 'trivial correlation'[28]. Fluctuating thermal conditions in the course of a year may be a contributing factor to the annual variation of the frequency of cardiac infarction. This, however, cannot be proved in such a manner.

Similar large correlation coefficients would be produced by a regression analysis with other elements such as radiation, humidity or air pollutants. These trivial correlations can also occur with regression analyses of weather classifications. For example the classes with undisturbed weather situations have a maximum frequency in summer, while the disturbed weather situations have, in most cases, a winter maximum. Since the infarct frequency also has a winter maximum, the probability that a large number of cases will coincide with bad weather phases and a smaller number with good weather phases is higher than vice versa. This means that a trivial correlation also exists here since the relationships are produced by similar annual rhythms.

This statistical effect in a number of older studies has probably led to an overestimation of the negative effect of 'disturbed' weather conditions and of the positive influence of high pressure weather. A positive influence of high pressure weather throughout the year is not causally explicable, since weather conditions with heat load in summer and with high pollutant concentrations in winter are predominant under these conditions.

The cause of the mistaken statistical interpretations lies in ignoring the time-series character of the data. Since the end of the 1970s many medical-meteorological studies have avoided such trivial correlations[6,12,16], by initially applying filter operations to the data before using the classical statistical methods.

Another possibility for avoiding trivial correlations is separate monthly or seasonal processing. This is, however, only possible when longer series are available. Using this technique, very good results have been achieved[6,23,25,29]. One can imagine only a few effects of weather that occur throughout the year with the same type and intensity. This requires that studies of meteoropathological disturbances should always include temporal differentiation. How fine this temporal differentiation has to be depends on the influencing factors themselves. The effect of air pollutants during the semi-annual periods of winter and summer can be expected to be, in each case, qualitatively equal influences. The proof of thermal influences during the four meteorological seasons requires a seasonal division of the material being studied, whereas proof of the effects of light requires a monthly division. This is due to large fluctuations during the seasonal transition periods.

A further cause of difficulty in establishing medical-meteorological relationships lies in the question of latency times. Every statistical model makes the assumption that after a constant time a stimulus produces a reaction. This is a considerable simplification since meteorological stimuli themselves require varying time spans, for example, weather change, duration of a thermal load and its penetration into indoor areas. Furthermore, the time required for the organism to react differs depending upon the functional system and interindividual differences. This leads to considerable temporal blurring, so that possible relationships are difficult to determine.

Statistical studies were carried out using numerous individual meteorological elements or combination variables which closely correlated with one another. A relation exists between temperature, solar radiation and pollutant concentration, i.e. between the leading factors of all three complexes of effects. Weather classifications are also characterized by certain combinations of meteorological elements. A causal interpretation of such statistical relationships is, strictly speaking, not possible. This is because there are always several influence factors to be considered. On the other hand, it is the complex weather conditions which comprise the total influence on the organism. It is only the weighting of the individual complexes of effects which differs according to the season and the affected organic system.

The significance of the influence factors can only be recognized using a differentiating analysis. For example, a predominant influence of the photoactinic complex is inferred if the correlation to global radiation is closer than to temperature. A possible synergism of the effect of cold and pollutants on respiratory illness is assumed if the frequency of illness generally rises during weather conditions with little air exchange, but is higher in highly polluted areas than in areas with clean air. Medical data series are often influenced by interference factors, which have to be eliminated before completion of the statistical analysis, because they increase the variance to such a degree that no more reliable relationships can be proven. During holidays and vacation times there is a change in the amount of illness recorded. This happens because the living habits, the organization of health care or the population potential also changes in the area that is being studied. Influenza epidemics strongly influence many data series. When there is a high frequency of colds the general mortality and the frequency of cardiac infarction also increase.

In spite of the difficulties just discussed the influence of short-term changes in the atmospheric environment on health and well-being has been conclusively proven. This conclusion is based on statistical analysis and the numerous individual studies that have been conducted. The success in applying medical-meteorological weather classifications to show the correlation between meteorological conditions and medical data is probably the special suitability of the weather classifications in the use of statistically standardized methods. The success is also due to the ability to portray a time-based sequence of changes in meteorological elements in a way that is medically relevant[18].

Results of medical-meteorological studies

Weather as an effect-accord

In the last four decades results correlating medical data with weather have been produced within the framework of medical-meteorological research. These results are based on varying classifications and statistical methods. They have, however, created a rather uniform picture of these relationships. Certain areas have become prominent, in which an accumulation of events in differing medical areas has proved to be highly significant. The relations can be described as follows[3,27]:

- the maximum biotropic intensity lies in the area of the greatest weather changes, and here biotropy increases with change in intensity;
- the changes in the thermal environment associated with change in air mass significantly influence the type of meteorotropic reaction. The maximum is located on the warm advective air side of the front part of a low and in the area of the most unstable layered cold air at the rear of a low;
- the biotropic minimum is found in the center of a high; with the formation of a strong inversion in the lower troposphere, thermal and air-pollution stress factors must be considered; and
- the biotropic effect of weather is also affected by geographic-climatic factors and annual and diurnal courses. In addition, the reaction of the human being is also dependent upon individual predispositions.

In order to achieve a meaningful organization of the many results of medical-meteorological studies, a uniform classification criterion is necessary, e.g. pathogenetic aspects. The most frequently studied pathological areas are transport disturbances (predominantly disturbances in heart and circulatory system), and organic defence mechanisms (especially infections and hormone production).

Transport disturbances and defence mechanisms operate in the humoral, the incretoric (in the area of secretions) and in the neural areas[5]. Table 2 shows a

Table 2. Weather and disease (selection)

Weather class	1/2	3/9$_2$	4	5	6	7	8/9$_1$	10/11	12	13
Migraine			●					●		
Headache		●	●		●	●				
Quality of sleep		●	●	●		+				
Subjective impairment in well-being		●	●	●						●
Accident proneness			●	●						
Blood clotting		●	●							
Thrombosis			●							
Embolism			●	●						
Predisposition to inflammation			●	●					●	
Hypotensive reaction		●	●					+		
Cardiac infarction	+		●	●	●	●		+		
Cardiac insufficiency	+		●			●		+		
Apoplexy						●				
Angina pectoris	+				●	●				
Rheumatical arthritis					●	●	●			
Hypertensive reaction					●					●
Spastic disease		●				●				
Colics						●	●			
Diabetes						●				
Suicide		○	○							
Phantom limb pain			●			●				
Psych. depression			●	●						

●significant correlation; +beneficial influence; ○correlation with limitations selection of research results. The statistical relationship between the 13 weather classes of the Freiburg objective weather classification and the different medical areas are shown here. Overlapping cannot be discounted in this table.

The accumulation of relationships for the weather phases 3, 4 and 5, which are predominantly warm air phases, is clearly recognizable. This is also the case for cold air advection, class 7. Individual medical areas show relationships with several weather phases. This is because the temporal changes are predominantly responsible for the biotropic stress. For some medical areas, such as accident proneness, sleep disturbances, embolisms and cardiac infarction events, steady thermal load conditions (class 5) can also lead to a higher frequency of occurrence. This in additon to a change in meteorological environmental conditions, which also leads to an increased frequency.

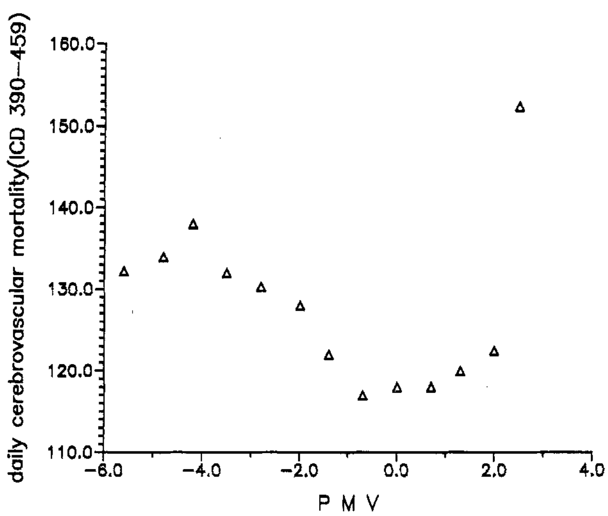

Figure 2. Mean daily cerebrovascular mortality and thermal stress (PMV = Predicted Mean Vote) in SW-Germany 1968–1984.

The significance of the complexes of effects for the total weather accord

To characterize the complexes of effects and their significance for the weather accord, invididual elements can be employed, if these elements work as a leading parameter, which has the strongest effect on the complex or which has a relationship with the other individual variables.

Temperature represents a very imprecise leading parameter for the thermal complex. In addition it is often a false leading parameter for thermal conditions surrounding the human being. The comfort index PMV (Predicted Mean Vote) has been developed, which is suitable for parameterizing the thermal effects[8, 17]. In additon to air temperature this comfort index considers radiation conditions (short- and long-wave), air movement, and humidity with respect to heat loss of the human organism.

The sunshine duration is often the only parameter that can be used to characterize photoactinic effects. There is a relatively close correlation between global radiation, UV-radiation and light, so that the use of a radiation variable is often sufficient for epidemiological purposes. The correlation, however, varies seasonally. For example, in winter even in radiation-intensive weather conditions there is only a small ultraviolet portion. This is due to the low position of the sun. For the complex of air quality effects sulfur dioxide and dust can be used as leading parameters in winter while in summer ozone is used.

Complex of thermal effects. The thermal effect of weather is the influence on the heat budget of the human being, its thermoregulation and other autonomic regulation systems. Within the total accord of effects the thermal complex is only relevant under the following presuppositions. These are geographical, orographical and environmental conditions with a high dependence on season. The intensity of the reaction of the human being to the thermal complex is primarily dependent upon the person's health. The cardiac and circulatory responses play a dominant role in the reaction of the organism to thermal conditions. Numerous medical-meteorological studies have been carried out on these responses, using death statistics[1, 11, 19, 22, 29]. The results show the importance of the thermal complex and, in spite of the strong parameterization of the thermal environment, agree in general that a maximum number of deaths occurs in winter and a minimum in summer. In the latter case, however, there is a relative maximum number of deaths on days with high heat load. This was confirmed by a study, done in Baden-Württemberg, of the variance of the number of deaths caused by cardiac-circulatory problems[6]. This study employed the so-called Predicted Mean Vote (PMV) as an indicator of the deviation from comfort conditions in a thermal environment (fig. 2). Here the influence of thermal stress is clearly recognizable. It shows an increasing number with a rise in cold stress (negative PMV values) and a marked elevation when the critical heat load (PMV greater than 2.0) is exceeded. The comparison of the number of deaths with the objective Freiburg weather classes shows that in the summer quarter with weather situations characterized by an advection of warm air and anticyclonal dynamics (weather classes 5 and 12), an accumulation of days with an increased number of deaths occurs (fig. 3). This agrees with other studies carried out at the same geographical latitudes, e.g. in Canada[20]. The comparison discussed was carried out using a seasonal partitioning of the data.

The human organism is affected not only be the static thermal situation, but is also affected by the changes in

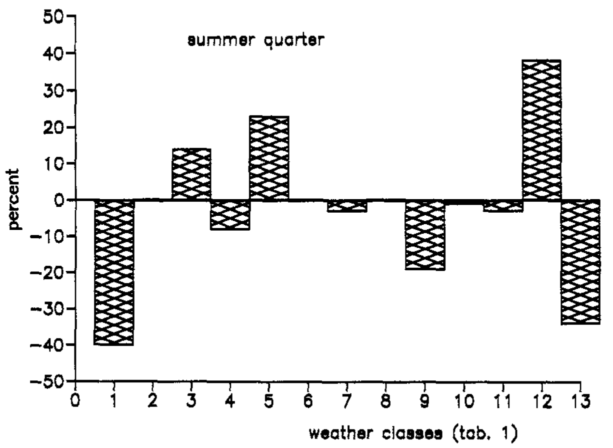

Figure 3. Deviation in percent of days with increased number of deaths (heart and circulatory system) from the corresponding expected values under varying weather conditions (Baden-Württemberg 1978–89).

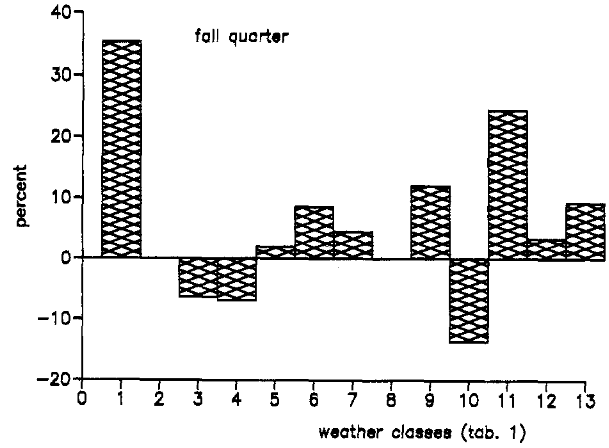

Figure 5. Deviation in percent of days with increased number of deaths (heart and circulatory system) from the corresponding expected values under varying weather conditions (Baden-Württemberg 1978–89).

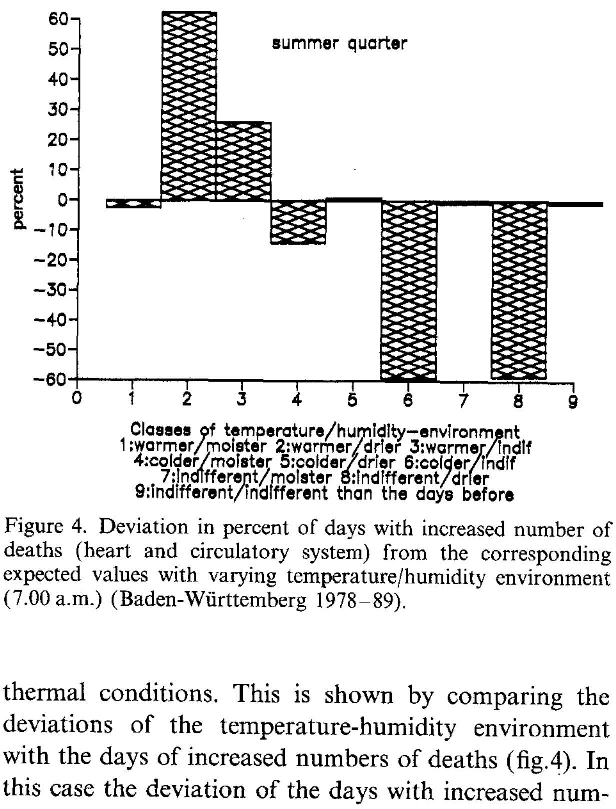

Figure 4. Deviation in percent of days with increased number of deaths (heart and circulatory system) from the corresponding expected values with varying temperature/humidity environment (7.00 a.m.) (Baden-Württemberg 1978–89).

thermal conditions. This is shown by comparing the deviations of the temperature-humidity environment with the days of increased numbers of deaths (fig.4). In this case the deviation of the days with increased numbers of deaths from the expected value was more than 60%. This occurred in a temperature-humidity environment where the dry-bulb temperature changed markedly in comparison to the preceding days. The change in humidity plays a subordinate role.

The importance of seasonal differentiation for medical-meteorological studies is shown in figure 5. In the fall quarter increased numbers of deaths are noted during completely different weather conditions. These conditions are predominantly anticyclonic (classes 1, 9 and 11). This implies that the influence of low air-exchange conditions played a role.

The complex of air quality effects. Studies of the meteorotropic influence of pollutants are not concerned with the chronic effects or with individual pollutant components. They focus on the part that the pollutant mixture plays in the development of meteoropathological disturbances. The most relevant pollutant mixture is the one that currently occurs in industrial areas during weather conditions with a low degree of air exchange. In spite of the amount of work on air pollution effects, there are relatively few definitive studies with temporal components. These studies are often concerned with data on diseases related to smog periods. Possible increases in disease during or after periods of bad air quality, however, may be undiscovered due to the great variability of the data. This is sometimes caused by important interference factors such as influenza epidemics, holidays, etc. If weekly or monthly illness frequencies are compared, a possible influence can be obscured. This can be due to the 'harvesting' effect: after an increase in illness resulting in deaths, fewer seriously ill people are present. The result is that a number of studies do not consider it proven that an acute deterioration in health occurs during smog periods[10,15].

Longitudinal studies, which are not based on single smog periods, often do not satisfy the methodical criteria mentioned above. So, for example, Wichmann[32], along with others evaluating epidemiological studies concerned with air pollutants and pseudo-croup, did not find a simple reliable study with temporal components.

Wintry smog periods are always coupled with low air exchange and often with low temperatures. In statistical relationships an adverse effect of cold, high relative humidity and low radiation is generally documented. So some studies showed an increase in bronchial illness during periods of low temperature. These illnesses were less pronounced in areas with fewer pollutants than in

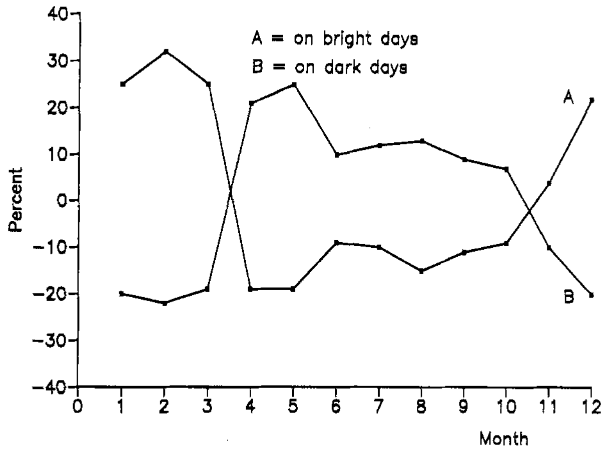

Figure 6. Deviation of the frequency of acute dental disease from expected values on bright and dark days

areas with high pollution levels. This implies a combined effect of meteorological and air-quality stress factors[12,33]. Therefore in the evaluation of biotropy at high pressure conditions in winter the thermal conditions and the negative effects of pollutants have to be considered separately.

The effect of the so-called summer smog with ozone as the leading substance has only aroused public interest in Europe in recent years. Then there is also the problem of the simultaneous effect of several pollutants, heat and direct solar radiation. These are additional stress factors that are dependent on the weather conditions. One must, however, take into account that thermal and actinic factors may decrease the exposure to ozone, as older or sick people are likely to avoid going outdoors on days with heat stress. As a result they will be exposed to relatively low ozone dosages. Because the dosages are primarily dependent upon the breath-minute volume, the main risk groups may be people who work or are active in sport outdoors, as well as children[30] (see also Wanner in this review).

The complex of photoactinic effects. Light has a major influence on the human organism. Light conditions change not only seasonally but also show large interdiurnal fluctuations in connection with weather changes. For example, with an elevation of the sun of 23 ° there can be intensity change of 18,000 lux between a cloudless and cloudy sky[35]. To understand the significance of seasonal processes in the organism light and UV-radiation have long been used as indicators[13,24]. Interdiurnal light changes, however, can only rarely be related to meteoropathological disturbances[14].

Klinker[23] found a relationship between the frequency of different complaints and radiation conditions. Figure 6 shows an increase in dental diseases on days with above normal global radiation during the semi-annual winter period and during below normal periods in the semi-annual summer period. Stress is thus created by conditions which run counter to the expected seasonal conditions to which the organism has become adapted. This adaptation has occurred either through endogenously or exogenously conditioned annual rhythms. A light effect is probably responsible, because a simultaneous processing of thermal conditions produced no or considerably smaller correlation. The cause is assumed to be regulatory disturbances, which could lead to changes in the immune system.

Light has also been shown to affect psychology[34] as well as hormone regulation. Bright light and strong contrasts produce ergotropy, a mood that promotes activity and work, whereas dull and low contrast conditions have an activity retarding effect. Light is particularly used in therapy of winter depression[21].

Application of research results for consultation

The mean contribution to different medical events by meteorological factors or complex variables lies between 10 and 20%. For extreme meteorological conditions it is considerably higher. This corresponds approximately to the share that certain risk factors such as smoking, overweight, high blood pressure, and high cholesterol level have for cardiac and circulatory diseases. The significance of the influence factor 'weather', which can also serve as a multiplier for other risk factors, is of such a magnitude that accurate information for certain risk groups is clearly necessary. Therefore the German Weather Service offers medical-meteorological information to the public as well as to medical facilities. This information is available through various media, such as telephone recordings and newspapers. It is based on the comprehensive material that has been gathered in the last forty years, stemming from various international medical-meteorological working groups and research facilities which worked independently of one another and carried out their work on a statistical basis.

Using the objective biosynoptic analysis of weather as well as the calculation of heat load and cold stress from a complete heat balance model (Klima-Michel-Modell[17]), a connection between meteorological conditions and the reactions of the human organism can be established. This relationship can be current, predicted or retrospective. In this way it is possible to provide weather dependent risk factors. This is of use to doctors and patients in the discussion of suitable behaviour, correct diagnosis, and therapy. In addition it can help the healthy person improve or optimize his quality of life.

Further goals for the use of medical-meteorological information include[9]:

- providing reassurance, since transient complaints or reduction in performance can be caused by weather;
- the possible long-term adaptation of treatment for

patients with, for example, heart disease or migraines, or those experiencing pain;
- adjustment of physical activity based on weather conditions; avoidance of overexertion;
- adjustment of spa treatment for spa patients;
- adoption of an appropriate attitude to weather-dependent complaints when travelling into unaccustomed climates; and
- anticipation of increased risk of complications during anaesthesia and preventive surgery on emboli and for internal bleeding.

A pilot study which was carried out in 1985[7,9] was crucial for public information. A questionnaire which involved 1136 doctors determined that 64% of those questioned felt that daily information about the influence of weather on certain medical problems would be 'helpful'. Only 5% rejected such a service. At the same time 81% of patients that were questioned felt such a service would be helpful or at least partially helpful. It was felt that one of the advantages would be the improvement of their own acceptance of short term impairments to their well being.

For spa and for climate therapy, biosynoptic information provides an important supplement to the application of the bioclimate to specific problems. An appropriate therapeutic dosage of weather stimuli and the optimization of the dose-dependency can enhance the adaptability of autonomic regulating systems to changing environmental conditions. This would result in a positive effect on the condition of the organism.

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