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Weather and acute cardiovascular attacks: statistical analysis and results

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Key words. Biometeorology; cerebrovascular accident; meteorology; myocardial infarction; predictor; weather type.

1. Introduction

This study deals with the onset of cardiovascular critical phenomena among a human population. A review of published biometeorological studies in this field shows that a great many have been carried out, but most of the results are not supported by precise criteria of statistical significance. Therefore we shall first introduce in this article a synthesis of the results of French studies conducted in the Paris area, which will lead us to develop the methodology which has been used. Next we shall compare these results with those from three other selected studies. The French studies have been conducted within specific spatio-temporal limits, i.e. in a town where critical data have been compiled constituting the statistical population of the study. Indeed, the elaboration of these medical files permits us to ascertain once more a seasonal distribution of the crises with a maximum in the colder period, a fact already well known for a temperate climate[13]. However, our purpose is different; our specific goal is to answer the following question: To what extent could the onset of myocardial infarctions or cerebrovascular attacks be accounted for by short-term meteorological or environmental changes?

2. Biometeorological methodology

2.1 Spatio-temporal aspect

It is necessary in order to study the comparative evolution of the atmospheric situation and the daily number of cardiovascular attacks compiled by a medical service to ensure a certain spatio-temporal unity:

– the clinical cases observed at the emergency medical unit originate from a limited zone (e.g. a city, circa 100 km^2) and the study must reject from the files external cases resulting from long distance transportation;

– the meteorological synoptical station taken as a reference station for the calculation of biometeorological predictors is representative of the local atmospheric variations induced by the evolution of the weather.

The basic time unit used for the elaboration of the medical files on the one hand and the meteorological files on the other hand is the day (0–24-h period). The basic spatial unit is the topoclimate[4].

2.2 The medical files

They must collect a large number of cases on the basis of strict clinical criteria. In that respect records of deaths

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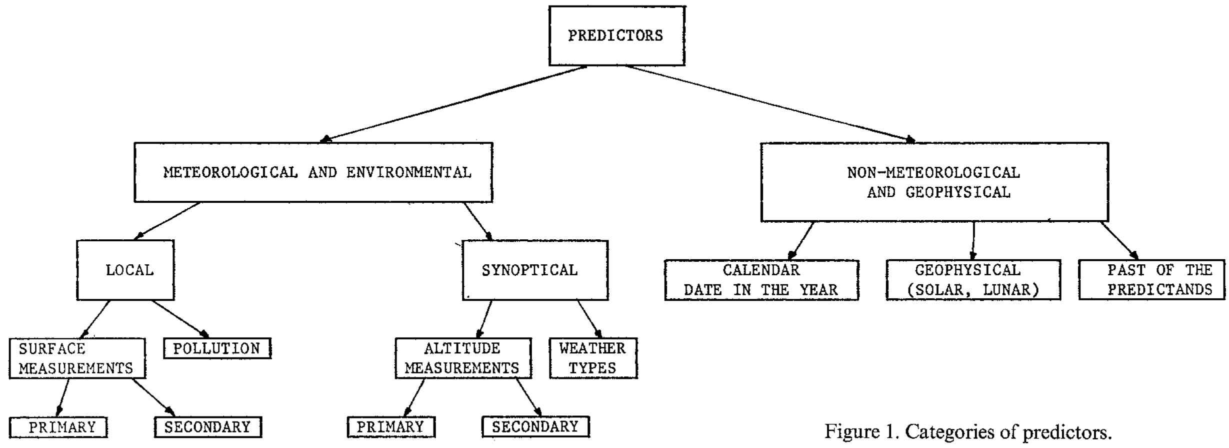

Figure 1. Categories of predictors.

from cardiovascular attacks are much too clinically inaccurate to be used. The French studies rely on basic data from emergency medical units located in the western part of Paris and its western near-suburbs, a densely populated area. These units are composed of squads specializing in rapid on-the-spot medical interventions. This study spans three years (1975–1977). For every case the hour of the beginning of the crisis is precisely determined. Two types of cardiovascular attacks have been studied:
1) threatening syndromes of myocardial infarction with a typical and prolonged anginous complaint not surrendering to a dose of trinitrine, and abnormal electrocardiographic signs of ischemia and lesion together with abnormal enzymatic levels.
2) cerebrovascular accidents, with a sensorial and motor deficiency either with or without loss of consciousness. The hour of the crisis is sometimes hard to determine because of some cases of night paralysis that are known only the next morning. Table 1 indicates the number of cases observed. The period from Christmas to New Year has been excluded from the study.

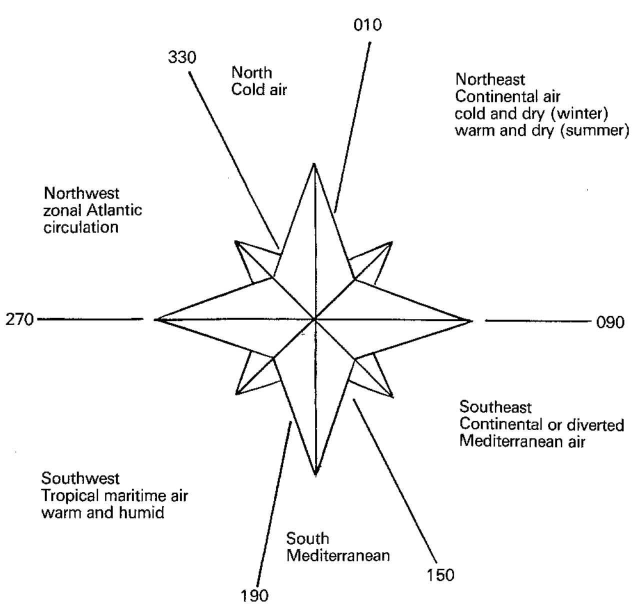

Figure 2. Wind sectors (Paris area).

2.3 Biometeorological predictors

Let us recall that every explanatory variable introduced into the statistical analysis is called a *predictor*. Every variable included in the daily meteorological files may as such constitute a predictor. These variables may be transformed or combined: calculation of biometeorological indices, coding of variables. Moreover non-meteorological factors can also be taken into account. Figure 1 indicates the different categories and sub-categories of predictors. A list of predictors used in different French studies is given in table 2; they fall into five different types: 1) so-called 'surface' meteorological measurements at a synoptic station; 2) altitude measurements; 3) weather types; 4) non-meteorological predictors; 5) pollution measurements.

Every quantitative variable may be transformed into a coded variable in order to reveal possible threshold effects. For meteorological variables already codified, e.g. wind direction, a coding into six wind sectors is done, grouping wind directions likely to be linked to the same synoptical origin, as shown by figure 2 for the Paris area. The choice of predictors is a crucial step in every biometeorological study. The quality of these 'predictor' files determines the refinement of the statistical analysis and the possibilities of interpretation.

2.4 Statistical methods

Whatever the particular statistical method, it is necessary to constitute two separate files: 1) The *medical files* consisting of an indicator variable, for every day of the period of study, of the occurrence of the critical phenomenon. This variable, either quantitative (daily number of cases), or qualitative (a 2-mode code), constitutes the variable to be explained, or predictand. 2) The *meteorological files* are composed of a certain number of explanatory variables. These are quantitative or qualitative (or coded) variables. Hence two different methods may be used: either a univariate analysis, or a multivariate analysis. Let us examine the principles of theses two methods.

2.4.1 Univariate analysis. This method, also called unidimensional, takes every daily biometeorological predictor individually. For every predictor the range of its possible values is divided into a number of disjointed classes. Every day of the period is fitted in its corresponding class.

Every class must include a minimum of five days. The Bernoulli statistical test is calculated

$$BERN(k) = \frac{KC(k) - KT\frac{NC(k)}{NT}}{\sqrt{KT \cdot \frac{NC(k)}{NT} \cdot \left(1 - \frac{NC(k)}{NT}\right)}}$$

with
NC(k): the number of days belonging to class k
NT: total number of days of the study
KC(k): number of clinical cases counted for all the days of class k.
KT: total number of clinical cases of the study.
This test is in fact a 2-class KH12 test
if BERN (k) > 1.96 then $p < 0.05$
if BERN (k) > 2.6 then $p < 0.01$

This method enables threshold effects to stand out. It is used for every season with a definition of meteorological seasons commonly used in climatology[4]. Then there remains to see whether a grouping of days in the same statistically significant class (e.g. $p < 0.05$) corresponds to a particular weather type. A class corresponding to extreme values of the predictor may be easily interpreted but the number of cases will be low.

2.4.2 Multivariate analysis. This is based on a linear discriminant analysis particularly suited to the case of a 2-mode qualitative predictand (high value: class A/low or mean value: class $\bar{A}$). For this analysis a threshold is fixed, separating two populations of days. If S equals 3 cases of myocardial infarctions per day we are interested in predicting the days when the number of cases recorded exceeds S (class A). First an automatic sorting out of predictors makes it possible to separate between useless and useful parameters through a stepwise forward selection which classes the predictors by range of decreasing informativity. The informative quality of the first group of k predictors is estimated via a quality index called the Mahalanobis distance (see bottom of table 3). The square of this index (Δ^2) increases at each step of the selection with the complementary information brought by the predictor selected at range k to the previously selected group of (k-1) predictors. The increase of Δ^2 weakens when no additional information comes up. At this stage we have a group of k selected parameters (e.g. k equals 10, see table 3) which are introduced into a linear discrimination[5,7], with a view to predicting.

The qualitative coded predictors used are transformed into quantitative variables for the stepwise forward selection through the 'optimal scaling' method[8]. This method consists of attributing to every class of the qualitative or coded predictor a numerical coefficient which enables us to arrange classes, which means that two classes are near, in relation to the predictand, when they have neighboring coefficients.

Table 1. The medical files

Period: 1975–1977	Western Paris	Western suburbs
Myocardial infarctions	744 cases	1966 cases
Cerebrovascular attacks	229 cases	701 cases

Table 2. List of predictors

1) Meteorological measurements at a surface station

Simple:
- wind speed at synoptic hours
- daily minimal and maximal air temperatures
- mean dew-point temperature $\overline{Td}$ (or $\bar{e}$)
- mean air temperature $\overline{Ta}$

Elaborated:
- $\Delta\overline{Td} = \overline{Td}$ (J) – $\overline{Td}$ (J-1)
- $\Delta\overline{Ta} = \overline{Ta}$ (J) – $\overline{Ta}$ (J-1)
- daily maximal 3-hourly variation of atmospheric pressure
- daily maximal 3-hourly variation of Td
- index of air dryness, function of $\overline{Ta}$ and $\bar{e}$
- wind sectors
- crossed classes ($\Delta\overline{Td}$, $\Delta\overline{Ta}$)
- index of stormy weather (cloud types)
- deviation of simple predictors from their climatic mean

2) Altitude measurements:

Simple: potential wet bulb pseudo-adiabatic temperature
Elaborated: precipitable water, vertical temperature profile, daily variation of precipitation water (24 h)

3) Weather types:

Synthetic: 10 types
Automatic classification

4) Non-meteorological:

Date in the year/day of the week/solar activity/lunar phase/magnetic storm/past of the predictand

5) Pollution measurements:

- Strong acidity concentration (SO_2 equivalent)
- Black smoke concentration

3. *Results: interpretation and discussion*

In this section we shall first present our results. As the two different methodologies outlined in section 2.4 (i.e. univariate and multivariate) give different results, they will be presented separately, which does not mean that they are contradictory. But the particular characteristics of each methodology condition what type of results can be obtained. Nevertheless it is not possible to give the percentage of clinical cases triggered by weather phenomena. We can only indicate how frequently such and such a meteorological situation occurs. Then our results are compared to those from other studies, and finally a few suggestions as to how the physiopathological aspects could be investigated are given.

3.1 Univariate analyses

These results have been interpreted in terms of the corresponding meteorological situation through the examination of the synoptical maps for the days belonging to a statistically significant class. For myocardial infarctions two typical situations have been outlined: 1) arrival of an active frontal disturbance characterized, in relation to the surface predictors, by a sharp decrease of dew point temperature right after the cold front, or a rapid decrease of sea surface atmospheric pressure ahead of a frontal system; 2) advection of a tropical humid air quantitatively outlined by an air humidity index (water vapor pressure 2.5–3.5 millibars over its climatic mean for the corresponding temperature of the air mass) and by a noticeable increase of the precipitable water (1–1.2 cm in 24 h).

Table 3. Result of the stepwise forward selection for myocardial infarctions (Paris area 1975–1977)

Range	Predictors	Δ^2
1	Weather type	1.052
2	Past of the predictand (number during the last 4 days)	1.337
3	Wind speed at 18 GMT	1.528
4	Index of seasonal variation	1.625
5	Pollution index 1: daily mean concentration of strong acidity	1.699
6	Pollution index 2: daily mean concentration of black smokes	1.795
7	Wind sector at 18 GMT	1.864
8	Vertical thermal gradient (between ground and 500 m) at 12 GMT	1.916
9	Pollution index 3: maximal concentration in strong acidity	1.968
10	Wind speed at 6 GMT	2.013

Note: Δ stands for Mahalanobis distance. The Mahalanobis distance Δ is a measure of the distance between the two matrixes composed of the values of the predictors in two cases: X(A) = matrix of predictors in the A case (more than S medical cases); X($\bar{A}$) = matrix of predictors in the $\bar{A}$ case (less than S medical cases).

For cerebrovascular accidents the arrival of a cold and dry continental air Northeasterly (particularly encountered in late winter and early spring) is an aggravating situation (abnormally low value of daily mean dew point temperature, less than −5 °C).

3.2 Multivariate analysis

The results apply only to myocardial infarction[6]. A synthetic coded predictor, made up of 10 weather types or weather changing types and introduced into the multivariate discriminant analysis, proved the most informative (classed number one in the stepwise forward selection, see table 3). In this table one can also notice that out of the first ten selected predictors, three refer to the wind (wind speed and wind direction), and another three are pollution indices. The main result of this study has been to establish four aggravating weather types, either due to a change in the atmospheric situation or a strengthening of a particular weather type. A limited description of these types is given in table 4. As can be seen in this table the occurrence of any of these types is a rare phenomenon. Over this three year study they occurred only on fifteen percent of the days of the period, with two-thirds of the occurrences in autumn or spring.

3.3 Discussion and interpretation

The biometeorological literature in the field of cardiovascular accidents is abundant, but the comparison of the results is particularly difficult for two main reasons: 1) some results are not backed with criteria of statistical significance; 2) results obtained in different climates must be interpreted in relation to the characteristics of these climates, particularly their thermometric and hygrometric regime. Therefore we shall limit our discussion to three publications[2,10,11], one from France (Larcan, 1982), one from West Germany (Brezowsky, 1965) and one from Japan (Ohno, 1974).

As was said in the introduction, the interpretation of the results must distinguish those which are specific to the effect of rapid fluctuations of the atmosphere in relation to the arrival of a meteorologically disturbed system or to a change in the air mass, from those which are only related to the seasonal distribution of the acute attacks. Indeed, certain meteorological parameters show a marked annual cycle: this is the case for the air temperature, the relative humidity and the duration of sunshine. For example the fact that the class of daily mean air temperature less than 6 °C is a statistically significant class for the Paris area reflects in proportion the greater amount of cases of myocardial infarctions during the five coldest months of the year.

The Larcan study[10] covers 535 myocardial infarctions and 378 cerebrovascular attacks that occurred in the vicinity of Nancy (France). Two statistical methods were used: a univariate analysis and a factorial analysis of correspondence. The results show a greater frequency of infarctions in the presence of rainfall or other hydrometeors together with low atmospheric pressure, which is typical of a meteorological disturbance. Results for cerebrovascular atacks are less obvious from the meteorological standpoint.

The Brezowsky study[2] is based upon large files of myocardial infarctions (12888 cases) for which the clinical criteria were electrocardiography and autopsy. These data were compiled in about fifty West German towns situated in 12 different climatic zones. The study investigated both the seasonal distribution of cases, their spatial distribution and the possible influence of weather changes. Using his own scheme of weather phases[1] Brezowsky noticed an increased number of infarctions for two atmospheric situations: either ahead of a low pressure zone (phase 4) or west of a high pressure zone moving towards Central Europe (phase 3). In each case it is a warm advection; a warm and humid one in the first case. At ground level phase 3 comes before a simultaneous increase of air temperature and dew point temperature, which goes with phase 4 (Brezowsky names it the temperature-humidity environment, see reference 14).

The Ohno study[11] is based upon 1075 deaths from cerebral hemorrhage which occurred throughout the year 1965 in Nagoya (Japan), as well as upon a limited number of cerebrovascular attacks. A linear multiple regression analysis was carried out using 12 meteorological factors. It appeared that the effect of meteorological factors is most noticeable upon deaths from hemorrhages. The main four relevant factors are air temperature, variation of temperature gradient, variation of humidity gradient (curvature observed on graphic recording), and atmospheric pressure variation. Air temperature classed number one shows a negative correlation i.e. the lower the air temperature the higher the number of deaths from hemorrhages. In Japan cerebrovascular accidents are known to occur during very cold winters and in the colder areas of the country. As a conclusion to this paragraph the following similarities can be noticed: Regarding *myocardial infarctions:* 1) effect of a meteorological disturbance outlined both in Paris and Nancy (France); 2) similarity between Brezowsky's phase 4 and Cohen's types 1 and 4 (both warm and humid advections). Nevertheless Brezowsky's weather phase analysis does not fit France the way it does Germany owing to different geographical situations, especially as regards the position of the two countries in relation to the Alps.

Regarding *cerebrovascular attacks* we have the effect of a cold and dry advection observed both in France and Japan. Still, we must bear in mind that the contrast between the cold and dry winter and the warm and humid summer is far more marked in Japan than it is in Western Europe.

3.4 A tentative physio-pathological interpretation

Such an approach, specifically medical as it is, does not make it possible for the time being to obtain precise data. Indeed, on the one hand a statistical result does not indicate a causal relation, on the other hand these results cannot be explained from the point of view of today's physiology. From this physiopathological point of view the seasonal factor must be distinguished from the study of aggravating weather types.

The higher frequency of myocardial infarctions observed during the winter months may be linked to a variety of causes not directly induced by weather. One can notice that the sudden breathing in of cold air may favor a coronary spasm. Therefore physicians recommend people suffering from cardiovascular problems to avoid breathing in cold air. Leaving overheated places (buildings, underground stations, vehicles...) in winter can cause pain. During a cold period too the cardiac work is increased because, owing to vasoconstriction, the resistance of peripheral vessels is increased. Other causes like nutrition, ways of living or job stress may account for the seasonal distribution of cases. The results of our study show a larger number of days characterized by an aggravating changing weather type in spring and autumn than in winter (table 4). This aggravating meteorological factor and the seasonal fluctuation overlap. The onset of a weather change requires from the human organism a physiological adaptation which will be less efficient in the case of a sick person.

An influence of the parameters of the atmospheric electricity (vertical electric field gradient, number of atmospherics) cannot be rejected but this hypothesis cannot be tested for lack of adequate physical measurements.

Regarding cerebrovascular accidents (CVA) the physiopathological aspect is even more difficult to investigate because it deals with a local blood circulation with efficient autoregulatory processes. Ohno et al.[11] mention in the discussion of their results that cerebral hemorrhages seem to be more influenced by outdoor meteorological factors or changes than cerebral thromboses. According to them an explanation could be provided by the fact that these hemorrhages occur more frequently outdoors and in an active state concomitant with an increase in arterial pressure. Similarly this result about CVA may be compared to the conclusion of a study conducted in France by Lanoe and al.[9] on the death rate of aged persons in a long-stay hospital unit. One of the results was an increase of deaths in a situation of cold and dry weather which might be linked to a dehydration phenomenon.

Table 4. Aggravating weather types for myocardial infarction: A brief description. Each day of the study is given a coded weather type. Out of the ten types defined, covering all possible meteorological situations, four types were found to be aggravating types for myocardial infarctions. 3 criteria were used to discriminate between the 10 possible weather types: 1) weather change or weather persistence; 2) cyclonic or anticyclonic circulation; 3) synoptical wind sector (determined from the isobaric direction). The 4 aggravating types are *all weather changes or aggravation* of the same type (strengthening of wind speed, of temperature change or storm activity)

Type 1: (2%)	Wind sector: south-east to south (130°–200°) Mediterranean air
Type 2: (3.5%)	Wind sector: north-east to south-east (20°–130°) Anticyclonic situation (Scandinavia)
Type 3: (3%)	Wind sector: north-east to south-east (20°–130°) Cyclonic situation
Type 4: (7%)	Wind sector: south-west (200°–250°) Advection of tropical maritime air Depression south of Iceland

The bracketed figure indicated below each type stands for the frequency of occurrence of this particular type. Altogether these types occur on 15.5% of the days.

4. Future applications

This retrospective study which spans three years and is limited to the near-suburbs of Paris made it possible to define types of atmospheric situations (table 4) which are an aggravating factor for acute coronary accidents. From these results a system of biometeorological forecasting has been set up at an experimental stage in Paris. But it is not possible to use all the selected predictors for several reasons; only the synthetic predictor (weather type), classed number one in the stepwise forward selection, has been taken into account. This implies a loss of quality of the decisional model.

It is interesting to mention the problems encountered in this project[3]. First of all, a loss of information occurs when one switches from the weather maps resulting from the analysis of observations, which have been used in this present study, to forecasted maps obtained as an output of the numerical forecasting model. There is ipso facto a change in the spatial scale (from about 50 km, the grid of the synoptical observations network, to 200 km, the grid of the forecasting model).

Moreover this type of biometeorological forecasting will apply most of the time to large urban concentrations of people as is the case for Paris and its suburbs. Several million people live within a limited area of a few hundred square kilometers, and forecasting on this small grid the time of occurrence of a weather change remains difficult with the information available from the general weather forecasting. This must necessarily be a short-term forecasting (24–36 h) and this information must be telexed to specialized hospital units such as the emergency medical units. Under these conditions an emergency unit could use this information to strengthen reanimation teams, make more beds available in reanimation units and increase means of conveyance (vehicles, drivers, medical attendants). A report of this forecasting will be made in order to determine whether useful information can be brought to these units.

5. Conclusion

There is a certain number of people within the population at large who are likely to suffer a myocardial infarction at any time. We must remember that the onset of a threatening syndrome of myocardial infarction is a very complex physiopathological process where many factors play their roles (age, sex, nutrition, smoking). Our results have shown that the 'weather change' factor is one among other factors in the onset of a myocardial infarction or of a cerebrovascular accident, but that the percentage of clinical cases really dependent on this atmospheric factor probably does not exceed ten percent of the cases. Far from being the only triggering effect, rapid fluctuations of the atmospheric situation have a marginal effect and are only an additional factor of risk in certain cases. It must be said that the physiopathological interpretation still remains to be done in the future. It will be facilitated by a better definition of clinical criteria and by the availability of computed medical files with a precise spatio-temporal definition.

A better knowledge of the circumstances of the onset of the crisis (was the patient indoors, outdoors or leaving a building?) would seem to be a useful element in future studies along with the introduction of the statistical characteristics of the microclimate within buildings in an epidemiological study.

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Influence of atmospheric factors on the rheumatic diseases

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Key words. Rheumatoid arthritis; gout; systemic lupus erythematosus; climate; weather; meteorology.

Introduction

A vast quantity of literature exists on the influence of atmospheric factors on the rheumatic diseases. This does not, however, translate into great knowledge or a complete understanding of these effects. A review of the literature reveals many reasons for this. Unfortunately, most of the published reports are anecdotal, superficial case studies, or simply personal statements of opinion unsupported by facts. One review of this subject contained 9 spurious or erroneous references out of 43 cited. Some of these spurious references have appeared in identical form in later papers on the subject. An additional problem with some of the published studies was the use of very small sample sizes. The result is a limited number of studies that contribute to our understanding of the effects of atmospheric factors on the rheumatic diseases. Perhaps the most detailed, consistent, accurate, and prolific researcher on the demographics and geographical distribution of the rheumatic diseases was J. S. Lawrence. A major effort was made to illucidate the relationship between meteorological variables and the rheumatic diseases from these studies. Unfortunately, this significant body of work is of only limited value in delineating the effects of atmospheric factors on the rheumatic diseases. This is due to the nature of the effects, rather than any defect in Lawrence's otherwise excellent and informative work.

Tromp's massive review[67] of medical biometeorology in 1963 includes a very useful section on the rheumatic diseases. Although some citation errors are present, the 266 citations listed represent the best literature review up to that time and includes both English and non-English language papers.

This review will attempt to show three aspects of the influence of atmospheric factors on the rheumatic diseases. 1) historical development of the literature, 2) significant discoveries or ideas, and 3) the current state of knowledge and/or theory.

Rheumatic diseases

The rheumatic diseases are an aggregation of diseases and syndromes that are primarily grouped together as a