

ENVIRONMENTAL VARIABLES AND THE RISK OF DISEASE

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ABSTRACT

Objectives. To study the relation between the risk of acute myocardial infarctions (AMI) and meteorological variables and the geomagnetic field, and to make a literature survey of the relation between environmental variables and the occurrence of disease.

Study Design. Register study and literature search.

Methods. Register data on AMI were analysed together with data on temperature, relative humidity, barometric pressure, the Arctic Oscillation, the earth's magnetic field, and changes in these variables. A PubMed search for studies on environmental variables and the occurrence of other diseases was done.

Results. There was no correlation between "static" weather variables and the number of AMIs. A temperature rise of one degree C was associated with an increase in the number of non-fatal AMIs by 1.5%. There was a strong correlation between the AO and the number of AMIs – a one unit increase in AO caused an increase in the number of surviving AMIs by 3.4 %, fatal AMIs by 5.1% and the number of sudden cardiac deaths by 8.3%. There was no association between the geomagnetic field and the number of AMIs. The literature study revealed that several other disease states were related to extremes of or changes in weather situations.

Conclusions. A change in weather, rather than weather extremes, was associated with an increase in the number of AMIs. The environment surrounding us is capable of causing both disease and symptoms. The triggering mechanisms are not known, though.

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Keywords: acute myocardial infarction, temperature, humidity, barometric pressure, Arctic Oscillation, geomagnetic field.

INTRODUCTION

A sometimes-hostile environment surrounds man, more often so in the arctic areas. Extremes of wind, temperature, air pressure, electric and magnetic fields are but a few examples. Some of these physical variables have obvious effects on mammals, like cold injuries, heat stroke, and burn injuries from electrical currents. There is, however, also growing evidence that less obvious and indirect effects of these physical variables can cause disease in man.

The most well studied area is the relation between temperature and the risk of having an acute myocardial infarction* (AMI), where different results have been obtained in different parts and climate zones of the world. There are also studies on the relation between the aurora borealis (northern lights) and diseases, some of them showing a relation, others none.

It is a commonly held belief that certain other symptoms and diseases are affected by

changes in our environment. Thus, there are studies on the relations between rheumatic diseases, blood pressure, stroke, intraocular pressure on the one hand, and weather variables and geomagnetic field variations on the other.

In this paper I will review our own studies on the relation between weather variables (1), the Arctic Oscillation (AO) (2) and the geomagnetic activity (3), and the risk of having an AMI. I will also make a review of the literature on the relation between other diseases and our environment.

The AO is a large-scale mode of climate variability and governs to a large extent the weather in the arctic and subarctic areas. It is measured as pressure differences between two observation stations, one in Iceland and the other on the Azores. When the AO is in a low phase (lower pressure over Iceland than over the Azores), cold weather is permitted to escape from the Arctic region, bringing cold and dry weather and storms further down south, affecting

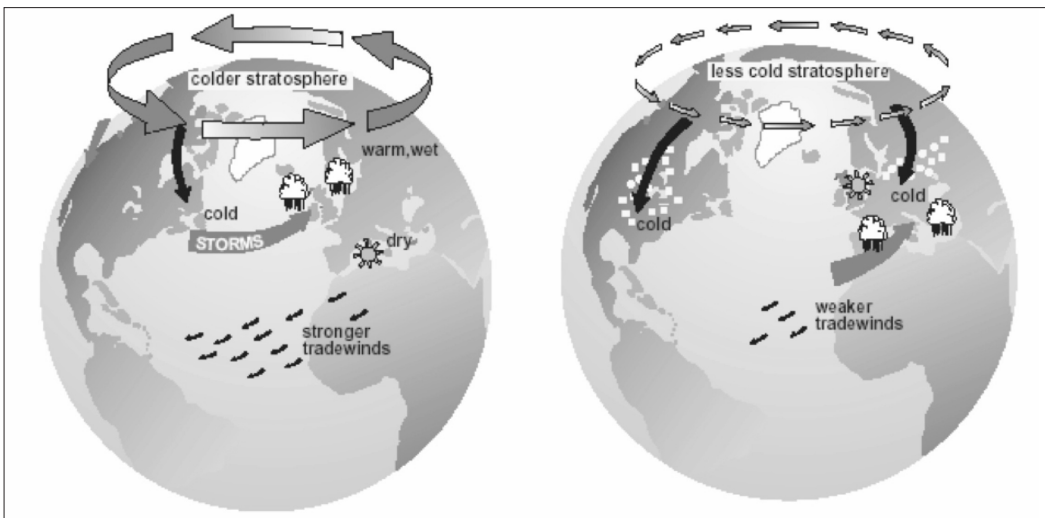


Figure 1. Mechanisms behind the high and low phases of the Arctic Oscillation, respectively. Reproduced with permission from David Thompson.

* A myocardial infarction is the death of muscle cells in the heart, being caused by the occlusion of a coronary artery. The consequence of a myocardial infarction is often reduced pump function, resulting in decreased physical performance.

Scandinavia. In a high phase, the cold air is contained within the Arctic area, the weather is warmer and more humid, and there is more cloudiness and precipitation throughout the Scandinavian subarctic areas (Figure 1). The AO affects not only the mean conditions but also the day-to-day variability (4).

The aurora borealis arises from a plasma (charged particles) colliding with the earth's atmosphere. The energy required to cause the auroras comes from the sun and the transmission system carrying the energy from the sun to the ionosphere consists of the solar wind and the magnetosphere of the earth. There is always a circle of northern lights in the polar area. Its intensity is determined by, inter alia, the sun's magnetic activity that varies with an average period of 11 years. On average 2 terawatts hit the forward side of the magnetosphere each second but only a very small proportion penetrates it. The magnetic field change in the aurora zone during a solar substorm can reach over 2 microtesla, and the horizontal current in the northern lights can reach 1 megaampere (5).

MATERIAL AND METHODS

Our own studies were performed within the framework of the Northern Sweden MONICA (multinational MONItoring of trends and determinants of Cardiovascular disease) project. This project started in the 1980's as a multinational effort to monitor the epidemiology of AMI and stroke, and to follow the risk factor levels in the population. These objectives were met by keeping registers of AMI and stroke in geographically well-described

areas, and by carrying out population surveys at regular intervals.

By combining the AMI register and databases on weather and weather changes, on the AO, and on the geomagnetic field over time, respectively, the relation between these variables were followed on an ecological levels, although linked to individual AMI events.

The AMI registry

The area covered by the Northern Sweden MONICA Project is sparsely populated and covers 154 300 km² where 510 000 inhabitants live. There are about 270 000 men and women in the target population in the ages 25-64 years. Between 1985 and 1999 all hospitals and general practitioners in the area submitted copies of records from patients with a suspected AMI or angina pectoris, and with chest pain typical of myocardial ischaemia, lasting for more than 20 minutes.

Based on the information on medical history, symptoms, ECG, and cardiac biomarker levels, the diagnoses were validated according to strict MONICA criteria. Fatal cases were defined as those who died before day 28 after symptom onset. In these cases, information on the cause of death was obtained from the records and/or necropsy reports where available. Also, all death certificates for patients in the appropriate age groups were reviewed, which enabled us to find cases with sudden cardiac death (SCD) occurring outside hospital. In all our studies, both fatal and nonfatal cases, including cases with SCD, were included. In nonfatal events, only cases classified as definite infarctions were included, and in fatal events, in addition also possible and unclassifiable infarctions were included.

Weather and weather changes

During the time period 1985-1992 we obtained information on temperature, humidity, barometric pressure and precipitation from the Swedish Meteorological and Hydrological Institute. These data were collected every three hours from 36 weather stations in the area. With regard to weather, both a survival and a time series analysis were done. For the survival analysis, the information from the weather station located closest in space and time to each index case was chosen. For the time-series analyses, the information from all weather stations was collapsed to give a mean value for measured variables each day. The difference between this value and that of the preceding day was used in the analyses. The number of missing values for weather data varies, since the data sources differ between these two analyses.

The Arctic Oscillation

The values for the AO are expressed as indices of normalized, time-averaged barometric pressure. These values were collected on a daily basis and downloaded from the National Oceanic and Atmospheric Administration website for the time period 1985-1999 (6).

The geomagnetic field

The geomagnetic field data were obtained from a three-component digital fluxgate magnetometer with a sampling frequency of 1 sample per second. We used the standard K index, which has ten levels, from zero to nine. This value is obtained from the maximum deflection during each 3-hour interval of the two components parallel to the surface of the earth, X and Y. The scale is quasi-logarithmic. Zero corresponds to deflections of 0-15 nanotesla and

nine to deflections greater than 1.5 microtesla. The K index sum represents the sum over a 24-hour period of the 3-hour K indices.

The years surveyed included all of solar cycle number 22, which started in 1988, the end of cycle 21 and the beginning of cycle 23.

Statistical analyses

In the weather analyses, survival in relation to weather and weather changes was analysed with maximum likelihood logistic regression. The time-series database, with the number of AMIs per day was analysed with Poisson regression, separately for fatal and nonfatal cases. The Poisson distribution was checked by comparing the mean and the variance of the dependent variable, and the fit of the model was tested with a chi² goodness-of-fit test for each model. When the dependent variable was over-dispersed, and for check of serial correlations, negative binomial regression analysis was used as an alternative. To check the robustness of the models analysed, season was introduced as an indicator variable, as was a dichotomous variable for temperatures below and above 0 degrees centigrade.

In the AO analyses, Poisson regression was used as above. The analyses were also performed with the AO lagged 1-7 days to allow the AO to have a greater impact on the meteorological conditions. The Poisson regression models were checked as outlined above.

The magnetic field analyses were carried out using maximum likelihood logistic regression and Poisson regression methods. We adjusted for day of the week and month, since the attack rate in the highest on Mondays and Tuesdays, and in February. We also adjusted for the meteorological situation (barometric pressure, temperature and humidity). The

analyses were also carried out with a one-day lag between the geomagnetic activity and the number of AMIs. Since there was a significant trend with a decreasing number of AMI cases during the surveyed time period, a detrended analysis was also carried out.

In all analyses, a p value of 0.05 or less was considered statistically significant. All analyses were carried out with the statistical program Stata (versions 6, 7 and 8, respectively). The statistical methods are covered in greater detail in the original publications (1-3).

RESULTS

There was a wide variation both in the dependent and independent variables (Table I), allowing for a sufficient analysis. The number of AMIs varied between the different analyses since different time periods were covered, but ranged between approximately 3000 and 6000 together.

Weather and weather changes

There was no increased risk of death in an acute myocardial infarction with any of the static weather variables. The odds ratio (OR) for temperature was 0.999, for humidity 1.004, and for barometric pressure 1.003 (Figures 2a-c).

We did not find an increased number of acute myocardial infarctions, whether fatal or non-fatal, with any of the static weather variables (Figures 2a-c). Only a temperature change was associated with a significant change in the number of non-fatal myocardial infarctions – a temperature rise of 1 degree Celsius was associated with an increase in the number of non-fatal AMIs of 1.5% (95% confidence interval 0.3 to 2.7, $p=0.02$), (Figure 2d).

The Arctic Oscillation

There was no trend in the AO during the years surveyed. There were positive relations between both fatal and non-fatal myocardial infarctions and the AO. The strongest relations were seen when the AO was lagged three days (Table II, Figure 2e).

Geomagnetism

In the longitudinal analysis, there was no relation between the K index sum and either the number of fatal or non-fatal myocardial infarctions. There was no relation between the lagged numbers of AMI, whether fatal or non-fatal. We did not find any relation between the K index sum and any measure of AMI in the detrended analysis (Figure 2f).

Table I. Variability in dependent and independent variables.

	Min	Max	Mean	Median
Total AMIs number	0	7	1.6	1
Number of surviving AMIs	0	7	1.3	7
Number of deceased AMIs	0	4	0.3	0
Number of SCD	0	6	0.4	0
Temperature (°C)	-33.7	21.5	-0.3	0.5
Temperature change (°C)	-14.1	17.5	0.0	-0.08
Barometric pressure (hPa)	959.5	1048.5	1009.1	1009.9
Relative humidity (%)	42.1	97.8	78.0	79.5
Arctic Oscillation	-4.3	4.1	0.04	0.05
K index sum	0	64	22.2	22

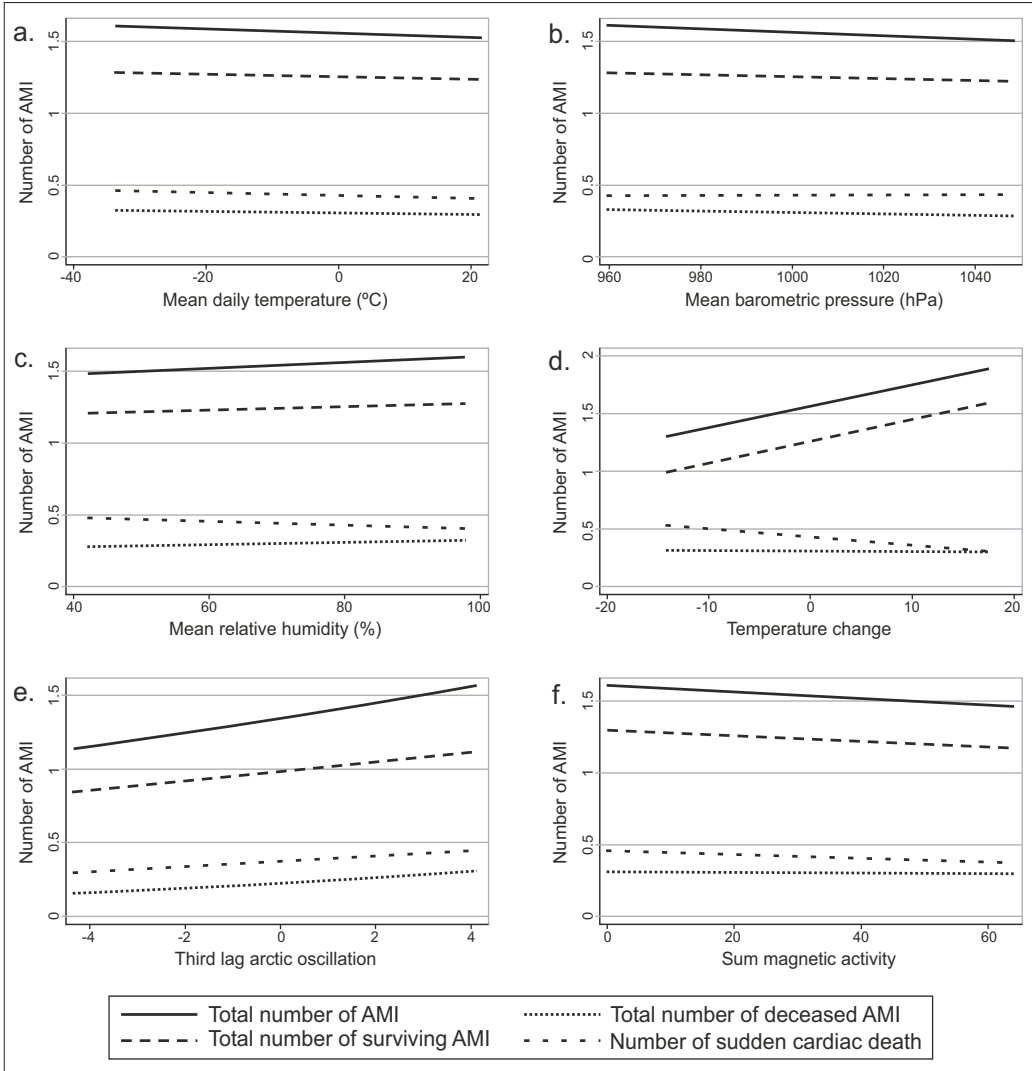


Figure 2 a-f. The relation between the number of acute myocardial infarctions and the mean temperature (a), the barometric pressure (b), the mean relative humidity (c), the temperature change (d), the Arctic Oscillation (e) and the geomagnetic activity (f).

Table II. Relation between the third lag AO and the incidence rate ratios of myocardial infarction.

	Incidence rate ratio	95 % CI	p
All AMIs	1.038	1.015-1.062	0.001
Non-fatal AMIs	1.034	1.007-1.062	0.001
Fatal AMIs	1.051	1.006-1.097	0.003
SCD	1.083	1.025-1.145	0.005

DISCUSSION

Environmental stressors cause both adaptation and other physiological reactions in the human body. In populations adapted to a cold climate, favourable changes in blood viscosity, von Willibrand factor (7), the rate-pressure product (8), and in total and LDL cholesterol (9) are seen.

Weather variables

The main finding, that a temperature rise could cause an increase in the number of non-fatal AMIs suggests that a temperature rise is associated with an increase in the incidence, not in case fatality. It could be explained by a disruption in the adaptation and cause an increase in the susceptibility to atherosclerotic diseases. Also other studies (10, 11) have shown an increase in the number of cases with increasing temperature.

There are observations that cast doubt on previously found associations between cold weather and an increasing risk of an AMI. Living at a higher altitude is associated with exposure to a lower temperature, yet there is a reduced incidence of acute myocardial infarctions (12-14). Also, the seasonal variations in the incidence of AMI is observed in equatorial countries where the temperature range is much lower (15).

Other factors than cold can account for part of the excess mortality in AMI in wintertime. Weight gain is more common in the winter (16) and less time is spent on outdoor physical activities. It has been shown that physical activity is associated with a reduced risk of coronary heart disease but the benefits are reduced a short time after cessation (17). Physical activities undertaken on a seasonal basis do not confer any significant cardiopreventive effect (18).

Our finding that the number of AMIs increase with increasing temperature is corroborated by the finding that an increase in the AO causes an increase in both fatal and non-fatal AMIs. An AO increase results in a warmer and more humid weather situation in Scandinavia and the maximum impact occurs three days after the change in AO, which fits well with the lag-time in our analysis. A recent British study (19) found an association between a negative phase of the AO and an increase in ischaemic heart disease mortality, related to a low temperature. This study, however, used an analysis based on monthly and seasonal averages in AO and temperature, disregarding day-to-day changes.

The literature is scarce on reports on the effects of humidity and barometric pressure on myocardial infarctions. This study showed no effects, however, interaction effects between humidity and temperature were not analysed.

As always it is difficult to know what are random findings and true associations, respectively. In the AO study, we covered a time series of 5500 days, which increases the risk that small, clinically insignificant changes may become statistically significant. Also, from a statistical point of view, any two series with trends in the same or opposite directions are correlated. In this study, however, there was no trend in the AO. In the register studies, the ecological fallacy (20) could play a role since the persons who suffered an AMI maybe not were those who were most exposed to the risk factor. Yet, the consistency of our data, the consistent increase in incidence rate ratio with increase in lag up to day three, and the consistent results of the significance tests made a random phenomenon seem less likely, especially in the face of the register studies.

Geomagnetic variables

The earth's magnetic field affects living organisms. Birds, fish and insects use it for navigation (21). Several previous studies have found a correlation between ambulance calls for suspected AMI and stroke in Moscow (22) and AMI morbidity and mortality in St Petersburg (23). Two earlier US studies (24, 25), however, failed to show a relation between geomagnetic disturbances and mortality and stroke.

It is difficult to explain an increased number of arrhythmias and sudden cardiac deaths (26) as related to electrophysiological changes, in turn related to changes in the earth's geomagnetic field since, the magnetic field from a hairdryer is more than ten times larger than the changes seen during a magnetic storm (27). Most previous studies have used a proxy variable for geomagnetic activity (number of sunspots) and for the diagnoses (chest pain, ambulance calls, discharge diagnoses) instead of using validated diagnoses as the MONICA Project offers which could explain the discrepancy in findings between our studies and those of other researchers.

Other diseases

The influence of atmospheric conditions on well being and disease has been studied in many different settings and with both objective and subjective measurements. Also, among lay people many different symptoms are attributed to weather and weather changes, often being lumped together as "weather sensitivity".

Weather sensitivity

In Switzerland, föhn illness, comprising headaches, nausea, insomnia and aggravated rheumatism was described more than fifty years ago (28). Föhn winds in Italy, Germany, and

Bermuda have been associated with irritability, heart problems and worsening asthma (29, 30).

In a comparative study between Germany and Canada (31), surprisingly concordant results were recorded in surveys. About 50% considered themselves to be sensitive to the weather, the highest prevalence being found in the age groups above 60 years. In Germany, stormy weather (30%) and when it became colder (29%) were considered to affect health more than other weather types, whereas in Canada cold weather (46%), dampness (21%) and rain (20%) were more common. In Germany, the most frequent symptoms reported were headache/migraine (61%), lethargy (47%) and sleep disturbances (46%), while in Canada weather-sensitive persons reported colds (29%), psychological effects (28%) and painful joints (10%).

Stroke

The association between weather and season has been inconsistent across stroke types. Increased mortality due to ischaemic stroke, subarachnoid haemorrhage and intracerebral haemorrhage have been linked to cooler temperatures (32, 33). A recent Canadian study, in a climate characterized by a high variability in weather conditions, found no relationship with changes in weather parameters (34).

Solar magnetic activity has been correlated with ambulance calls for stroke in Moscow (22) but no evidence of a relation between geomagnetic disturbances and mortality in stroke was found in US studies (24, 25).

Blood pressure

A recent Bulgarian study (35) found an increase in arterial blood pressure with the increase of the geomagnetic level, irrespective of sex and medication. This increase started the day before the

rise in the geomagnetic activity and continued to increase until the second day after.

Rheumatic diseases

Many studies have addressed the influence of weather conditions on pain in patients with rheumatic diseases and fibromyalgia. A review article (36) concluded after a PubMed search between 1985 and 2003 that temperature and humidity have influence on the symptoms of rheumatoid arthritis. In a less defined condition like fibromyalgia, a Norwegian study (37) found no statistically significant relationship between fibromyalgic pain and the weather. An Israeli study (38) found that cold weather training was a risk factor for Achilles paratendinitis among recruits. The hypothesis that a decreased viscosity of the lubricant mucopolysaccharides in cold weather caused increased friction and risk for inflammation was put forward.

Migraine/headache

As for other diseases and symptoms, conflicting results concerning headache and migraine in relation to weather have been obtained. However, migraineurs are physiologically hyperresponsive to a variety of internal and external stimuli. Triggers include wine, chocolate and caffeine, stress or the sudden lack of it, changes in sleep patterns and hormonal fluctuations among women. Several studies have addressed the relation between headache/migraine and weather where both existing and non-existing relations have been found. Prince et al (39) found that 30 % were sensitive to a function of absolute temperature and humidity, and 15 % were sensitive to a changing weather pattern. However, also negative studies exist (40).

An Italian study (41) investigated the relationship between headache and geomagnetic activity, but found none. No relation between humidity, temperature and migraine, respectively, was found.

Miscellaneous

Small, uncontrolled, retrospective and often register studies have linked other disease stated to ambient meteorological conditions. Tahri et al (42) found in a multivariate analysis that stormy weather was significantly associated with ruptured oesophageal varices, and, in a univariate analysis, that full moon was negatively correlated.

Stoupele et al (43) found in a study from Lithuania that the number of oncology patient deaths was inversely correlated with solar and geomagnetic activity indices, and positively correlated with cosmic rays activity. The distribution of the deaths was also correlated with deaths from stroke and suicide, but not with deaths from ischaemic heart disease.

Conclusions and recommendations

There is as yet inconclusive evidence as to the effects of the meteorological variables on health, since the studies give different results depending on their origin. Probably geography, climate zones and human adaptation to certain climates play a role and can explain some of these discrepancies. Likewise there is conflicting evidence as to the effects of the geomagnetic field, whether measured directly or indirectly as sunspots, on health. These differences are more difficult to explain unless there is significant interaction between other environmental variables and the geomagnetic field on health.

There is also a probable negative publication bias. Many studies, failing to find an association between environmental variables, are probably not published, and many studies give conflicting results. Possible reasons for conflicting results could be (44)

- Community-based data are not being used
- The interaction between meteorological changes and accepted disease risk factors is likely to be complex
- Indirect effects of weather change, like changing rates of infectious disease
- Population differences
- Differences between areas with small and large climatic variations, respectively.

Since there are substantial knowledge gaps as far as the relation between health, weather and climate are concerned, continued research is essential. The effects of atmospheric conditions on health are small in relation to e.g. the effect of established risk factors like high cholesterol or a high blood pressure on the risk of having a stroke or a myocardial infarction, necessitating international collaboration.

The short-term and direct effects on health of a climate change are probably even smaller and more insidious. A continuous epidemiological surveillance of the diseases causing most death and disability would be required to detect such effects.

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