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Health-relevant influences of air substances and meteorological conditions

An investigation of the effects of ozone, nitrogen dioxide and temperature extremes using health data from the area of Augsburg.

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For a long time it has been known that exceptionally strong and long-lasting heat waves have negative health effects on the population, which is expressed in an intensification of existing diseases and over-mortality of certain risk groups. Often associated with heat are stagnant airflow conditions that cause a large increase in the concentration of certain air substances. Many of these air substances have a strong adverse effect on the human organism.

The aim of the project is to investigate the actual hazard potential of health-relevant air pollution- and climatological variables by quantifying the effects on human health of increased exposure to air constituents and meteorological extremes. Different multivariate statistical methods such as correlation analysis and regression models, extreme value analysis and individual case studies are used.

Research Questions and Goal

Research Topic

„Health-relevant influences of air substances and meteorological conditions “

Initial Question:
Are air hygiene and meteorological stress situations evident in the medical records?

What characteristics and significance do the relationships have?

Which weather conditions carry an above average high emergency room risk?

Which factor can be assigned the greatest hazard potential?

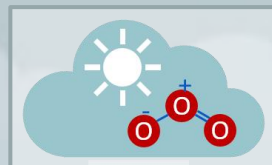
What are the most common environmental emergency cases?

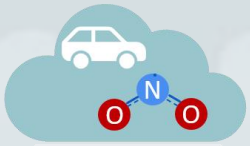
What are the health risks of climate change?

Weather forecast → increased likelihood of certain diseases

Air substances, climate and circulation patterns

High concentrations of certain air constituents are created according to an effect chain. Air pollution often arise in the context of certain air pressure constellations that favor the formation and accumulation of air pollutants in the troposphere through heat or low-exchange conditions.





Air Substances

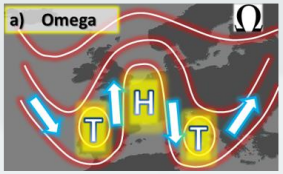
- Focus on O_3, NO_2, PM_{10}, $PM_{2,5}$
- Measured at various stations in Augsburg
- Provided: Bayerisches Landesamt für Umwelt

Climate

- Numerous meteorological parameters used
- Provided: Deutscher Wetterdienst

Example
Blocking weather conditions:

- Temperature extremes
- Low exchange conditions
- Dry spells



Synoptic Situations

- Responsible for current weather events
- Major role in the formation, decomposition process and the distribution of pollutants
- Provided: ECMWF ERA5

Health effects spectrum of air pollutants

Increased risk of stroke, dementia, Alzheimer's

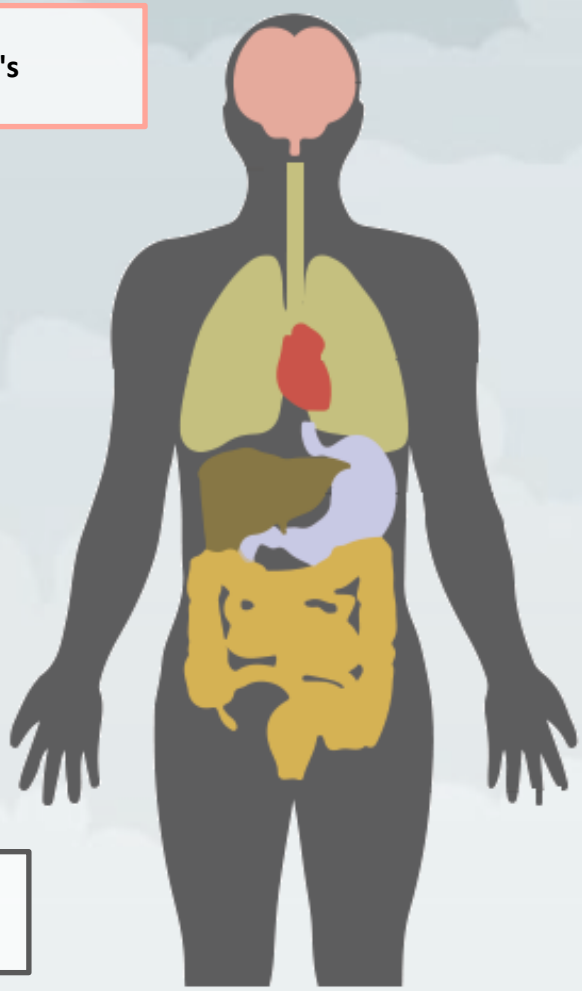
Increased mortality from respiratory diseases

Increased mortality from cardiovascular diseases

Increased risk of type 1/2 diabetes and gestational diabetes

Increased risk of pregnancy complications

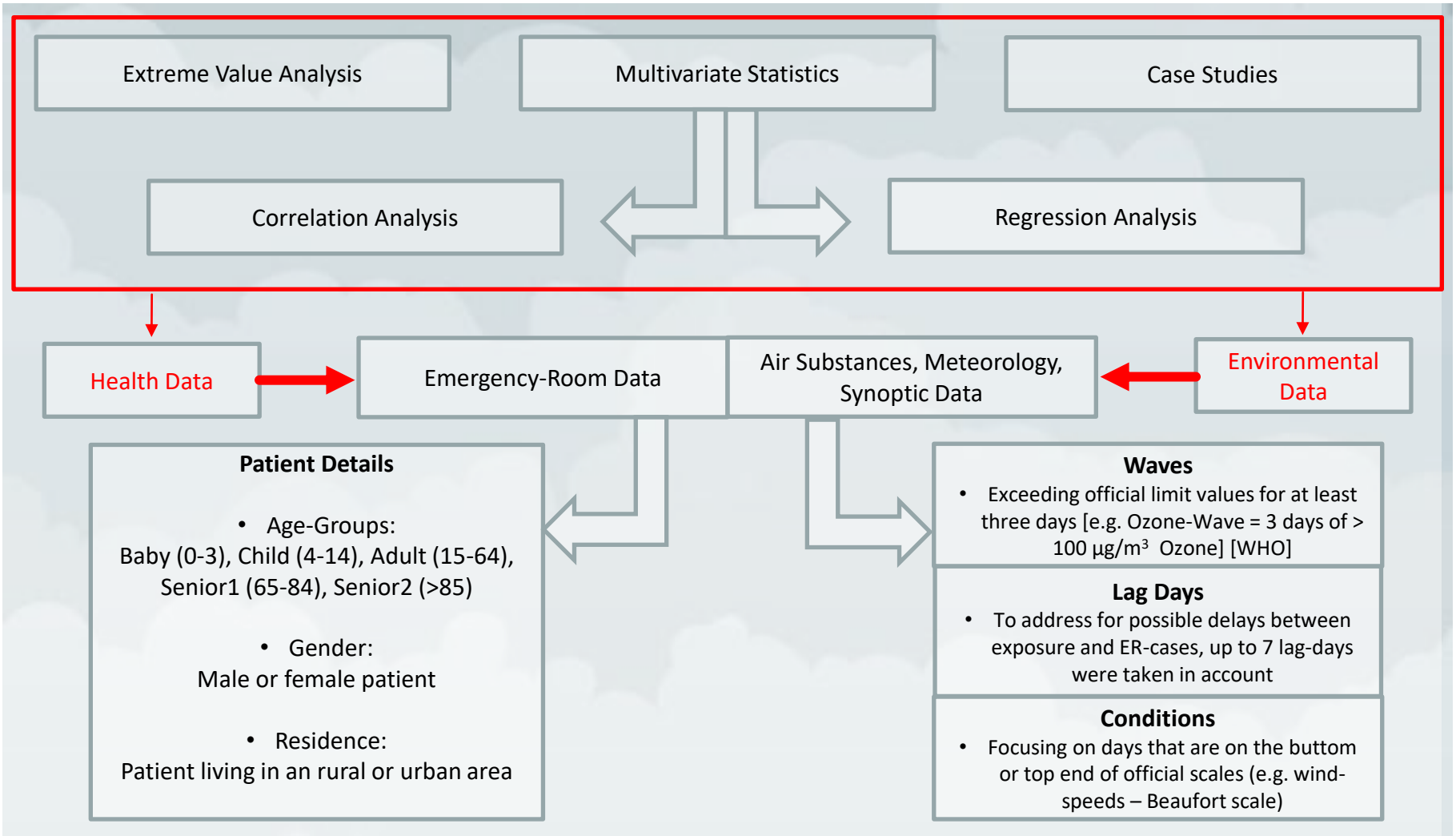
Accelerated skin aging and irritation of eyes, nose, throat and skin



Risk groups

- Babies, toddlers, children
- Pregnant women
- Seniors
- People with pre-existing conditions
- Intense outdoor activities

Methodological approach



Correlations - Overview

	J	J00	J02	J03	J04	J05	J06	J18	J20	J21	J22	J38	J40	J44	J45	J69	J96	J98	J00–J06	J09–J18	J20–J22	J30–J39	J40–J47	J90–J94	J95–J99	R05	R06
NO2_8hmax_Königsplatz	0.1	0	-0.1	-0.1	0	x	0	0.1	0.1	0.1	0.1	x	0	x	x	0.1	x	0	x	0.1	0.1	0.1	x	x	0.1	x	0.1
NO2_8hmax_Bourges_Platz	0.2	0	x	-0.1	0	x	0	0.2	0.1	x	0.1	0	x	x	x	0.1	x	0	x	0.1	0.1	0.1	0	x	x	x	0.1
NO2_8hmax_LfU	0.2	0.1	x	-0.1	x	x	0.1	0.2	0.1	0.1	0.2	0	0.1	0.1	x	0	x	0	0.1	0.2	0.2	0.1	0.1	x	x	x	0
Ozon_8hmax_LfU	-0.4	-0.1	0	x	-0.2	-0.1	-0.3	-0.3	-0.2	-0.1	-0.2	-0	-0.2	-0.1	0.1	x	-0	-0.1	-0.3	-0.3	-0.3	-0	-0.1	x	-0.1	-0	-0
Ozon_8hmax_Bourges_Platz	-0.4	-0.1	0	x	-0.1	-0.1	-0.3	-0.3	-0.2	-0.1	-0.2	-0	-0.2	-0.1	0	x	x	-0.1	-0.3	-0.3	-0.3	-0	-0.1	x	-0.1	-0	-0
PM10_8hmax_Königsplatz	0.1	0	x	-0	x	0	0	0.1	0.1	0.1	0.1	x	0	0	x	x	0	0.1	0	0.1	0.1	0.1	0	x	0.1	x	0.1
PM10_8hmax_Bourges_Platz	0.1	0	x	-0.1	x	x	0	0.1	0.1	0.1	0.1	x	0	x	x	x	0	0.1	0	0.1	0.1	0	0	x	0.1	x	0.1
PM10_8hmax_Karlstraße	0.1	0	x	-0.1	x	x	0	0.1	0.1	0.1	0.1	x	0	0	x	x	0	0.1	x	0.1	0.1	0	0	0.1	x	0
PM10_8hmax_LfU	0.1	0	x	-0.1	x	x	0	0.1	0	0	0.1	x	0	x	x	x	0	0.1	0	0.1	0.1	0	x	0	x	x	0
PM25_8hmax_Bourges_Platz	0.2	0.1	x	-0.1	x	0	0.1	0.1	0.1	0.1	0.2	0	0.1	0	x	x	x	0	0.1	0.1	0.1	0.2	0.1	0.1	x	0.1	x	0.1
PM25_8hmax_LfU	0.2	0.1	x	-0	x	x	0.1	0.1	0.1	0.1	0.1	x	0.1	0	x	0	x	0	0.1	0.1	0.2	0.2	0.1	0.1	0	0.1	0	0.1
DWD_FX	x	x	x	0.1	-0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DWD_FM	0.1	x	x	0.1	x	x	0.1	0.1	0.1	0.1	x	x	0.1	x	x	-0	x	x	0.1	0.1	0.1	x	x	x	x	0	0
DWD_RSK	x	x	x	x	x	-0.1	x	x	x	0	-0	x	0	x	x	x	0.1	x	x	x	-0.1	x	x	x	0	x	x
DWD_NM	0.2	x	-0	0.1	0.1	x	0.2	0.2	0.1	0	0	x	0.1	x	-0	-0.1	0	0.1	0.2	0.2	0.2	x	x	x	0.1	0.1	x
DWD_VPM	-0.6	-0.2	0	x	-0.2	-0.1	-0.4	-0.3	-0.3	-0.3	-0.3	-0	-0.3	-0.1	0	x	-0.1	-0.1	-0.4	-0.4	-0.5	-0.1	-0.2	x	-0.1	-0	-0.1
DWD_PM	-0.1	x	x	-0	x	0	-0.1	-0.1	x	x	0	x	x	-0	-0	x	-0	-0	0	-0.1	x	x	-0.1	x	-0.1	x	-0.1
DWD_TMK	-0.6	-0.2	0	x	-0.2	-0.1	-0.4	-0.3	-0.3	-0.3	-0.3	-0	-0.3	-0.1	0.1	x	-0.1	-0.2	-0.4	-0.4	-0.5	-0.1	-0.2	x	-0.2	-0	-0.1
DWD_UPM	0.3	0	-0	x	0.1	x	0.2	0.2	0.2	0	0.1	x	0.1	0	-0.1	x	0.1	0.1	0.2	0.2	0.2	0	0	x	0.1	x	x
DWD_TXK	-0.6	-0.2	0	x	-0.2	-0.1	-0.4	-0.3	-0.3	-0.3	-0.3	-0	-0.3	-0.1	0.1	x	-0.1	-0.1	-0.4	-0.4	-0.4	-0	-0.2	x	-0.2	-0	-0.1
DWD_TNK	-0.6	-0.2	0	x	-0.2	-0.2	-0.4	-0.3	-0.3	-0.3	-0.3	-0	-0.2	-0.1	x	x	-0	-0.2	-0.4	-0.4	-0.5	-0.1	-0.2	x	-0.1	-0	-0.1
DWD_TGK	-0.5	-0.2	x	x	-0.2	-0.2	-0.4	-0.3	-0.3	-0.3	-0.2	-0	-0.2	-0.1	x	x	-0	-0.2	-0.4	-0.3	-0.4	-0.1	-0.2	x	-0.1	-0	-0.1
Year_PC1	0.1	x	-0.1	0	0.1	x	0.1	0.1	0	x	0	x	0	x	x	x	x	x	0.1	0	0	x	x	-0.1	x	x	0
Year_PC2	-0.5	-0.2	0	x	-0.2	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2	-0	-0.2	-0.1	0.1	x	x	-0.1	-0.4	-0.3	-0.4	-0.1	-0.1	x	-0.1	-0	-0.1
Year_PC3	0.1	x	x	-0.1	0	x	0.1	x	0.1	0	0	x	x	x	x	0	x	x	0.1	x	0.1	0.1	x	x	x	x	x
Year_PC4	x	x	x	x	x	x	x	x	-0.1	0	0	x	x	x	x	x	-0	x	x	x	x	x	x	x	x	x	-0.1
Year_PC5	-0.2	x	x	x	x	-0.1	-0.2	-0	-0.1	-0.1	x	x	x	x	-0	x	x	x	-0.2	-0	-0.1	x	-0	x	x	x	x
Year_PC6	0.1	x	x	0	x	-0	0.1	0	0	0	x	x	0.1	0	x	-0	0.1	x	0.1	0.1	0	x	0.1	x	0.1	x	0
Year_PC7	-0.1	x	x	-0.1	-0	x	-0.2	x	-0.1	-0.1	x	x	x	x	x	-0	-0	x	-0.1	x	-0.1	x	x	x	-0	x	x
Year_PC8	x	0	x	x	x	x	0	x	x	x	x	x	x	x	-0	x	-0	x	0.1	x	x	0	-0	x	x	x	-0

Tab.: Correlations between Diseases of the respiratory system and air quality, meteorology and synoptic (data: 2017-2018)

Legend

red = neg. corr, green = pos. corr, x = not significant (p-value > 0.05)

Illnesses

J Diseases of the respiratory system
J00 Acute nasopharyngitis [common cold]
J02 Acute pharyngitis
J03 Acute tonsillitis
J04 Acute laryngitis and tracheitis
J05 Acute obstructive laryngitis [croup] and epiglottitis
J06 Acute upper respiratory infections of multiple and unspecified sites
J18 Pneumonia, organism unspecified
J20 Other acute lower respiratory infections
J21 Acute bronchiolitis
J22 Unspecified acute lower respiratory infection
J38 Diseases of vocal cords and larynx, not elsewhere classified
J40 Bronchitis, not specified as acute or chronic
J44 Other chronic obstructive pulmonary disease
J45 Asthma
J69 Pneumonitis due to solids and liquids
J96 Respiratory failure, not elsewhere classified
J98 Other respiratory disorders
J00-J06 Acute upper respiratory infections
J09-J18 Influenza and pneumonia
J20-J22 Other acute lower respiratory infections
J30-J39 Other diseases of upper respiratory tract
J40-J47 Chronic lower respiratory diseases
J90-J94 Other diseases of pleura
J95-J99 Other diseases of the respiratory system
R05 Cough
R06 Abnormalities of breathing

Air substances, Meteorology and Synoptic Data

Air substances = daily maximum of No_2, O_3, PM_{10}, $PM_{2,5}$ in Augsburg
Meteorology = FX: wind max, FM = wind mean, RSK = precipitation, NM: cloud cover , VPM = vapor pressure, PM: local air pressure, TMK: temperature mean (in 2m), UPM: relative humidity, TXK: temperature max (in 2m), TNK: temperature min (in 2m), TGK: temperature min (on ground)
PC = Circulation Patterns after Principal Component Analysis of Air Pressure

Correlation - Overview

Possible explanations

- All infection related respiratory issues show much stronger correlations → spread of infections is related to weather conditions
- Temperature shows major neg. impact → respiratory issues seem to be more likely in cold weather
- Cloud cover → associated with temperature
- Relative humidity show pos. correlations
- Vapor pressure has neg. influence
- Circulation patterns: PC2 stands out with negative correlations → west winds with mild and humid air from the Atlantic Ocean in Germany

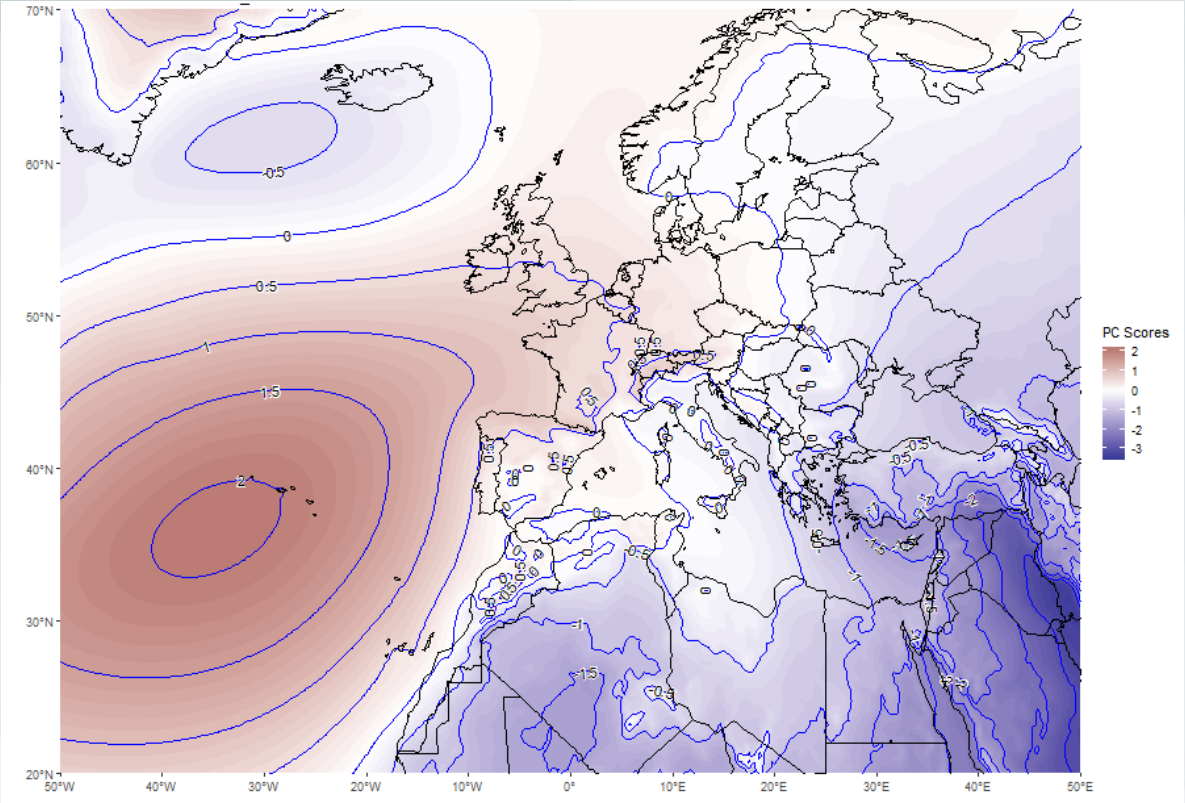


Fig.: PC2 Circulation Pattern

Strongest Correlations

Top 15 strongest positive and negative correlations

Variables	ICD10	Corr	A|G|R|L	Condition
PC2 (y)	R50-R69: Fever, headache, pain	0.92	A|F|-|L5	Humid
PM10max	I60-I69: Stroke, brain bleed	0.90	S1|F|-|L5	Low Pressure
PC2 (y)	S90-S99: Injuries (ankle, foot)	0.89	-|M|-|L3	Humid
PC2 (y)	L00-L08: Skin infections	0.89	-|M|-|L5	Humid
PC2 (y)	K55-K64: Diseases of intestines	0.88	A|M|-|L4	Humid
PC3 (y)	A00-A09: Intestinal infections	0.88	C|-|-|L5	Storm
O3max	T66-T78: Heatstroke, sunstroke	0.87	-|-|U|L6	Hot
PC2 (y)	S92: Fracture of foot	0.87	-|-|-|L7	Humid
PC4 (JJA)	N10-N16: Kidney infections	0.87	-|-|U|L7	Humid
PC8 (y)	S42: Fracture (shoulder, upper arm)	0.87	-|-|R|L7	Humid
PC4 (JJA)	S00: Head injuries	0.86	-|M|-|L5	Humid
PM25max	I60-I69: Stroke, brain bleed	0.86	S1|F|-|L5	Low Pressure
PC2 (y)	H30-H36: Eye inflammation	0.85	-|-|-|L4	Humid
PM10max	J20-J22: Bronchitis	0.85	B|-|-|L4	Low Pressure
O3mean	R51: Headache	0.84	A|-|-|L3	Storm

Variablen	ICD10	Corr	A|G|R|L	Condition
PC7 (y)	S90-S99: Injuries (ankle, foot)	-0.90	-|-|-|L3	Hot
PC4 (y)	I60-I69: Stroke, brain bleed	-0.89	S1|F|U|L4	Low Pressure
PC7 (y)	S80-S89: Injuries (knee,lower leg)	-0.89	-|M|-|L4	Humid
PC2 (y)	M40-M54: Spine, back diseases	-0.89	-|F|U|L6	Humid
PC3 (JJA)	M00-M25: Arthropathies	-0.88	A|M|-|L7	Humid
PC4 (y)	I63: Stroke	-0.87	S1|F|U|L6	Low Pressure
PM	I60-I69: Stroke, brain bleed	-0.87	-|M|R|L6	Hot
PC3 (JJA)	R00-R09: Abnormal heart beats, breathing	-0.86	-|F|-|L3	Humid
PC2 (y)	R55: Syncope and collapse	-0.86	-|-|R|L3	Low Pressure
PC4 (y)	M00-M25: Arthropathies	-0.86	A|-|-|L5	Humid
PC2 (y)	S00: Head injuries	-0.86	S1|F|-|L5	Humid
PC2 (y)	M54: Back pain	-0.86	-|F|U|L6	Humid
PC8 (y)	K92: Diseases of digestive system	-0.86	-|-|-|L7	Humid
TMK	G45: Cerebral ischaemic attacks	-0.84	S1|-|U|L4	Storm
PC4 (JJA)	H16: Keratitis	-0.84	A|-|-|L6	Humid

Most common circulation pattern at high correlations

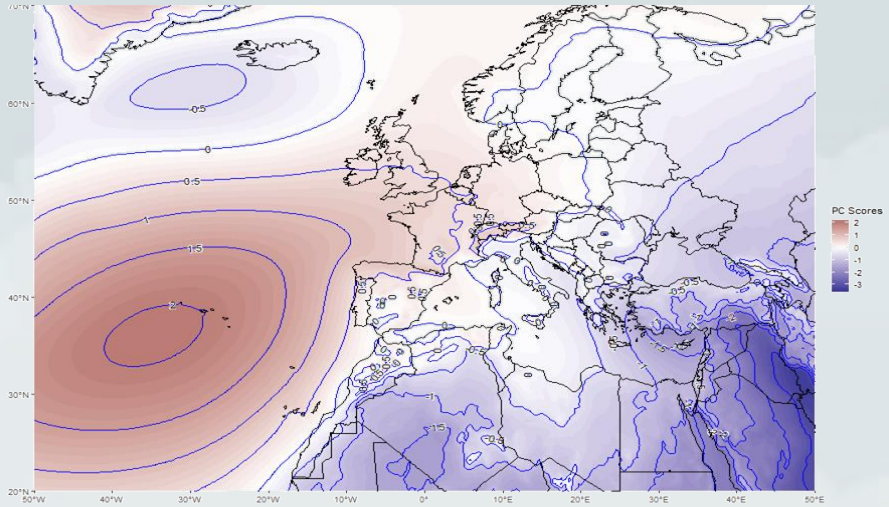


Fig.1: Average synoptic situation of the circulation pattern PC2 (y)

Weak anticyclonic north-west orientation
Mixed weather conditions

- Spring: Colder than normal; Precipitation below normal.
- Summer: Colder than normal; Precipitation below normal.
- Autumn: Colder than normal; Precipitation below normal.
- Winter: Warmer than normal; Precipitation tending to below normal.

Frequency of variables with negative correlations in selected diseases

Frequency of variables in selected diseases

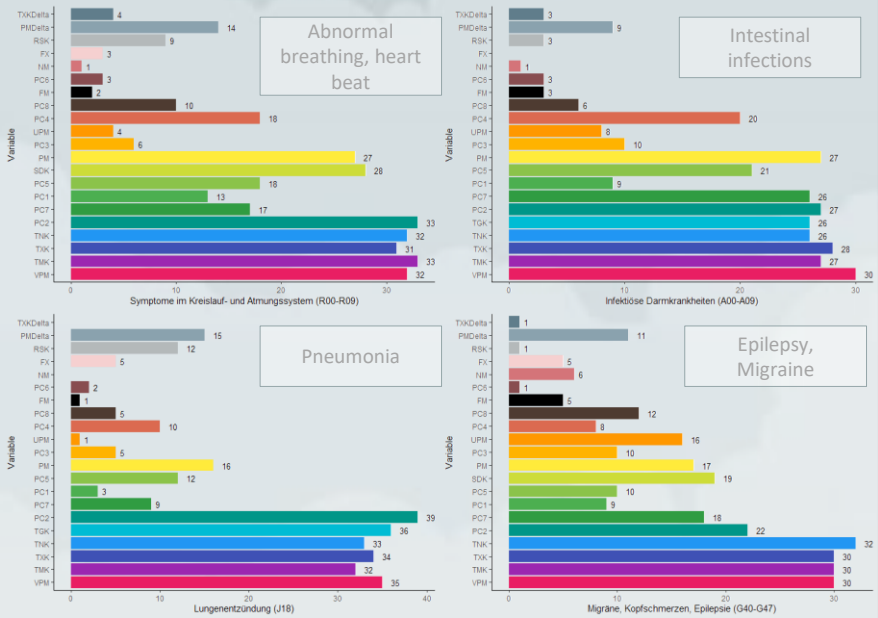


Fig.2: The most common variables with a negative correlation (negative correlations from -0.5)

Among all diseases, the most common variable with high negative correlations is vapor pressure (VPM). This is followed by all temperature variables (T). Sunshine duration (SDK), air pressure (PM) and relative humidity (RPM) also often have a strong negative correlation. Among the circulation patterns, PC2 has the greatest impact.

Top 10 most common diseases for selected variables (neg. correlations)

ICD	Description	T
R00-09	Breathing, heart beat	33
J18	Pneumonia	32
G40-47	Epilepsy, Migraine	30
I30-52	Heart disease	29
J20-22	Bronchitis	28
R07	Throat/Chest pain	28
K90-93	Digestive diseases	28
A00-09	Intestinal infections	27
J95-99	Respiratory diseases	27
I10	High blood pressure	27

ICD	Description	P
S06	Concussion	30
J09-18	Influenza, pneumonia	28
J00-06	Respiratory infections	28
R00-09	Breathing, heart beat	27
A00-09	Intestinal infections	27
B99	Infectious diseases	26
H0-50	Diseases of the eye	22
R07	Throat/Chest pain	20
N17	Kidney failure	20
G45	Ischaemic attacks	19

ICD	Description	V
J18	Pneumonia	35
R00-09	Breathing, heart beat	32
A00-09	Intestinal infections	30
J20-22	Bronchitis	30
G40-47	Epilepsy, Migraine	30
I30-52	Heart disease	29
J95-99	Respiratory diseases	28
I40-74	Heart, artery disease	27
I10	High blood pressure	27
K90-93	Digestive diseases	27

ICD	Description	F
S00	Head injury	27
T14	Injury (not spec.)	25
S50	Injury (forearm)	25
T66-78	Heatstroke, sunstroke	22
T51-65	Toxic effects (alcohol)	22
M54	Back pain	21
L00-08	Skin infection	20
M60-79	Soft tissue disorders	20
S90-99	Injuries (ankle, foot)	19
S20	Injury (thorax)	19

Fig.3: The most common diseases with a negative correlation (negative correlations from -0.5)

High negative correlations with temperature (T), air pressure (P) and vapor pressure (V) are predominantly found in diseases of the respiratory and circulatory systems. Diseases of the central nervous system and infections are also frequently associated with it. The negative correlations of the mean wind speed (F) are puzzling. So far, there has been no direct connection with the strong accumulation of injury-related illnesses.

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