JP1.23 ARE THERE ANY INFLUENCES OF METEOROLOGICAL CONDITIONS ON MORTALITY FLUCTUATIONS IN VIENNA, AUSTRIA?

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1. INTRODUCTION

There are different ways to explore relationships between weather and mortality. In numerous cases statistical methods were used to find some sort of temperature threshold (Kalkstein and Davis, 1989; Duncan et al. 1997, Davis et al. 2003); in other words the temperature beyond which mortality significantly increases. This method is particularly adaptive in areas, where the climate is not so variable. The climate of Vienna is characterized instead through changing weather patterns and distinct seasons. Weather conditions may cause a permanent stress for humans, especially older and/or ill people have a reduced capacity to adapt to external stimuli (Confalonieri et al., 2007). Death can be seen as a signal of a collapse of adaptation-systems, which can be partly influenced through changing weather conditions. In environments with fast changing external stimuli, like in the so called west wind dominated "temperate climate", is a time lag between weather and mortality. It is unknown how long each ones adaptation capacity could buffer external triggers, how big the trigger has to be in each individual and what the actual threshold of which trigger is for an individual.

A statistical significant relationship of mortality fluctuations during heat periods as well as a threshold morning temperature of 24°C for the summer months was found in Vienna (Thaler et al., 2005). In another study a threshold with different temperature variables, for example the Physiologically Equivalents Temperature (PET), was defined (Rudel et al., 2007). The effect of the heat wave 2003 was also studied (Hutter et al., 2007, Moshammer et al. 2008). These studies are all concentrated on heat-related mortality. In the present study, however, the whole year, including heat and cold periods, will be investigated.

The main objective of this study is to explore the influences of meteorological conditions on mortality in Vienna, Austria.

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2. MATERIAL AND METHODS

Ten years of daily meteorological and mortality data (1991-2000) were used for this investigation. Meteorological data (obtained from the "Central Institute for Meteorology and Geodynamics", Vienna), such as air temperature, humidity, cloud cover, sunshine duration, vapour and air pressure were measured at standard observation times 7:00, 14:00, and 19:00 (local time). In addition maximum and minimum air temperatures were used and equivalent temperature, dew point, and effective temperature were calculated.

Moreover, equivalent and effective temperatures were introduced, offering previous information about comfort and include a combination of air temperature and humidity. Table 1 summarized the different feeling classes for both temperatures (Auer et al., 1989).

feeling	equivalent temperature	effective temperature
sultry	> 56°C	> 24°C
slightly sultry	49,1 – 56°C	20,1 – 24°C
comfortable	35,1 – 49°C	16,1 – 20°C
chilly	< 35,1°C	< 16,1°C

Table 1: Classification of comfort feeling: equivalent and effective temperature (Auer et al., 1989)

"Statistics Austria" provided data on daily deaths in Vienna, which included age, sex and cause of death. For this study data on total mortality across all age groups and for the > 74 years old (all causes) was used. Nowadays the mortality in Vienna is higher during the winter and lower during the summer months (figure 1).

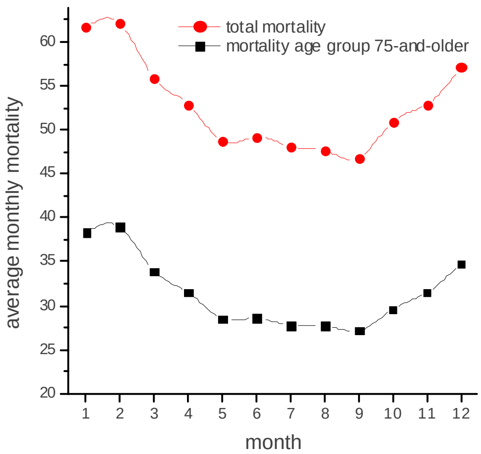


Figure 1: Average monthly mortality during the investigated period 1991 – 2000: total mortality and mortality > 74 years old

A sudden large increase or decrease in air temperature is not always associated with an immediate change in mortality rate. There is often a time lag between the mortality response and a given weather event (Boyd, 1960, Donaldson and Keatinge, 1997, Kunst et al., 1993). In order to find out if a time lag exists between weather and associated mortality a retarded response of one until seven days prior of the day of deaths were analysed. The interval where the heat plays the most important role is 1 to 3 days after the onset of a heat wave (Kalkstein and Greene, 1997), whereas cold spells have a longer lagged effect. To identify heat and cold periods the sum of the different temperatures from 2 until 7 days were used.

Two classification variables were established:

- Predominant synoptic features were chosen from Steinacker (1990) as synoptic system, based on different isobaric features predominant for the location. In this respect, main wind directions on the 850 hPa level with 10 different synoptic classes were considered (table 2, figure 2). Figures 3 and 4 show mean temperature and relative humidity within the different synoptic classes for the year as well as season's dataset.

synoptic class	**prevailing wind direction at the 850 hPa level**	**day numbers (1991-2000)**	**%**
0	Variable	988	27
1	North – East	143	3.9
2	East	146	4
3	South – East	177	4.8
4	South	114	3.1
5	South – West	285	7.8
6	West	329	9
7	North – West	365	10
8	North	147	3.9
9	Gradient weak	964	26.4

Table 2: Flow pattern classification from Steinacker, frequency and percent during the investigated period 1991-2000

- As second classification variable air pressure changes and their extreme values were used. The difference between the morning and evening measurements as well as between the evening and the following morning ones for each day was calculated. Afterwards extreme classes for every month, characterised by value larger than 1*Standard deviation (SD) above the mean as well as by values smaller than 1*SD below the mean, were defined.

Multiple stepwise regression analysis was applied to identify meteorological predictors of mortality using the different sub-sets of the two classification variables. Thus, the influences of meteorological conditions on mortality fluctuations within the year, seasons as well as months was investigated in order to find possible trends.

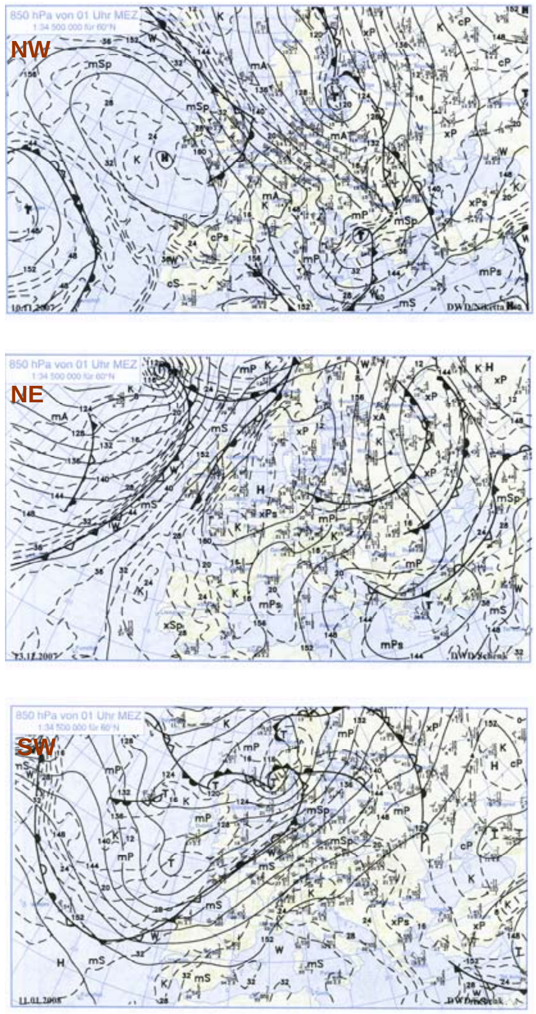


Figure 2: Examples prevailing wind direction at the 850 hPa level: North-West, North-East and South West

3. RESULTS

In a first stage the whole year was analyzed. A north wind has a highly significant influence on the mortality in Vienna and the model explains around 50% variance of total mortality (cases 141, sign. 0.00, predictors: sum7days of effective temperature at 14, air pressure7, sum5days of dew point temperature at 7, sum6days of equivalent temperature at 19, Tmax-1day). However, strong air pressure variations as classification variable could not reach such high r^2 by using the year dataset.

In a second stage seasonal effects were investigated. Total mortality shows to be highly influenced by east and south wind in spring, by south as well as south-west wind in summer and by north and north-west wind in fall (figure 5). Noticeable is the summer with the strongest correlations. The minimum temperature plays a decisive role by south wind and points out the importance of the cooling effect at night. The negative effect on mortality of high morning temperature was already found in our threshold study (Thaler et al., 2005).

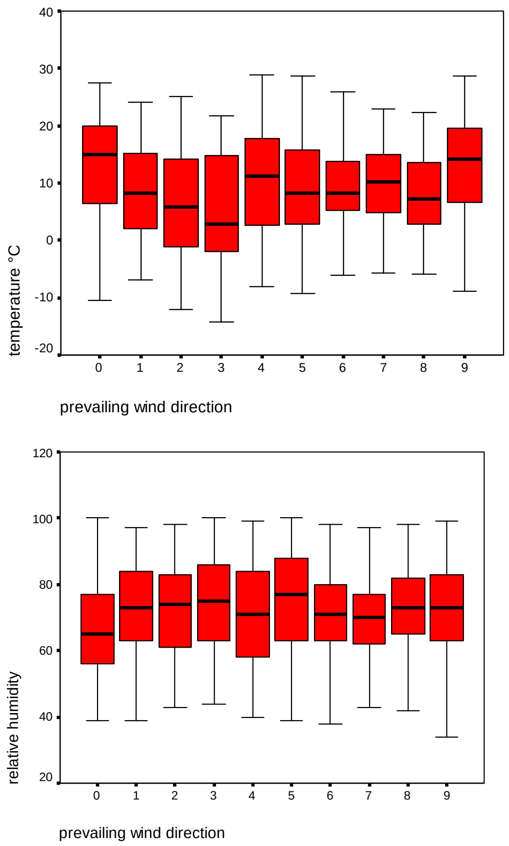


Figure 3: Mean temperature and relative humidity within the different synoptic classes for the year dataset

For the age group 75-and-older a significant high influence between different meteorological conditions and mortality is found in winter by north, north-east wind, in spring by north, east and south wind, in summer by north-east, east and south wind as well as in fall by north and north-west wind (figure 6). It seems that older people are more weather sensitive and vulnerable in winter in comparison to total population. In the other seasons marked differences between total mortality and mortality 75+ could not be found.

Extreme positive air pressure changes from the morning to the evening in summer (cases: 90, r^2 = 50% for total mortality and r^2 = 52% for age group 75+) is a further seasonal result.

Classification variable	total mortality	mortality > 74 years old
North	Feb, Jul, Aug, Sep, Dec	Feb, May, Aug, Sep, Dec
North-East	Jan, Feb	Jan, Feb
East	Apr, May, Jun, Aug	Mar, Apr, May, Sep
South-East	Feb, May	Apr, May
South	Oct	Jan
South-West	Aug	Mar, Jun, Aug
West	Jun, Sep	Jun, Oct
North-West	-	Jun, Aug

Table 3: High correlations (r^2 > 75%) between different meteorological conditions and total mortality as well as mortality > 74 years old within the classification variable: synoptic categories – monthly

In a last stage each month was analyzed separately. The main problem of this study was the frequency of cases for every month and synoptic class. Often there were not enough events and as limit 10 cases were used.

Each month shows different high correlations within the several synoptic weather patterns. In table 3 the months with the best model results (r^2 > 75%) for each weather pattern are summarized. Nevertheless further studies with longer time series should be attempted.

More cases and also high correlations are found by extreme air pressure changes for different months (table 4). Mainly an extreme air pressure change during day (from morning to evening) has a strong influence on total population in selected months; even though older people appear not to be really influenced. Air pressure changes during night shows more vulnerable months and the difference between total mortality and mortality 75+ is not so strong.

Classification variable	total mortality	mortality > 74 years old
+ pressure change: morning - evening	Jun (r^2 = 0.78, cases = 37) Nov (r^2 = 0.72, cases = 40)	Nov (r^2 = 0.73, cases = 40)
- pressure change: morning - evening	May (r^2 = 0.68, cases = 44) Jun (r^2 = 0.53, cases = 45)	-
+ pressure change: evening - morning	Jul (r^2 = 0.56, cases = 38) Aug (r^2 = 0.64, cases = 20) Dec (r^2 = 0.60, cases = 40)	Jul (r^2 = 0.76, cases = 38) Aug (r^2 = 0.82, cases = 20)
- pressure change: evening - morning	May (r^2 = 0.58, cases = 44) Jul (r^2 = 0.57, cases = 35) Nov (r^2 = 0.58, cases = 32)	Feb (r^2 = 0.78, cases = 37) May (r^2 = 0.56, cases = 44) Jul (r^2 = 0.61, cases = 35)

Table 4: High correlations (r^2 > 50%) between different meteorological conditions and total mortality as well as mortality > 74 years old within the classification variable: extreme pressure changes - monthly

4. CONCLUSIONS

A detailed exploration of the data set has uncovered many relationships between mortality and weather conditions in Vienna. Depending on the classification variables, thresholds and time lags, different meteorological variables and combinations of variables seem to influence mortality variability. However, the analyses do not reveal any single variable influencing mortality significantly and no single equation can be suggested explaining the complex link between weather and mortality in Vienna.

In further studies these relationships should be tested and proved with longer time series. The main aim will be to find simpler equations under the condition of a specific synoptic situation, which could be used as straightforward forecasting tool for special bio weather - warning systems. Synoptic weather patterns are generalized features of the atmospheric circulation with often similar meteorological conditions. The complex relationship between meteorological variable and mortality can be simplified throughout relationships of synoptic classes and their influence on mortality.

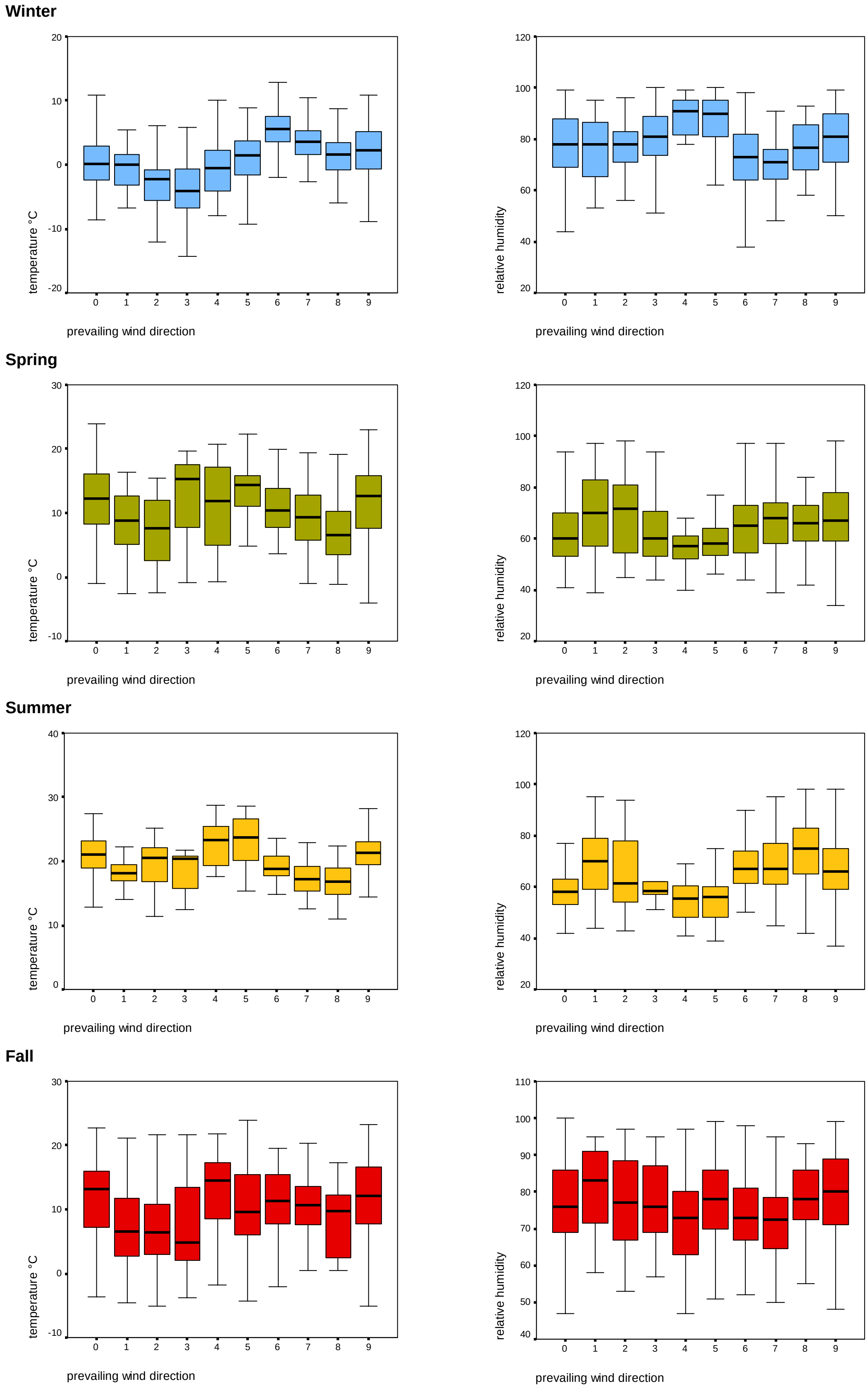
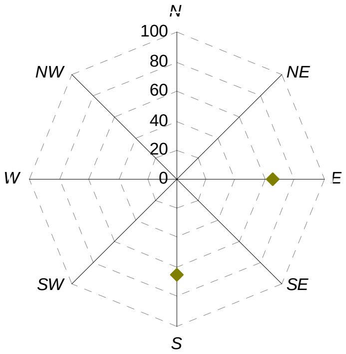


Figure 4: Mean temperature and relative humidity within the different synoptic classes for the season's dataset



Spring

East wind:

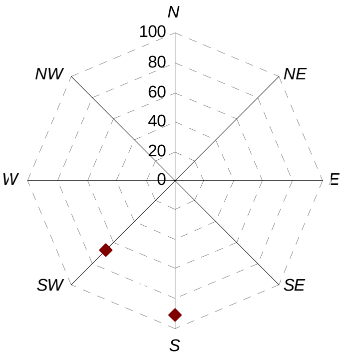
Cases: 35, r^2 = 65%; Predictors: Teff14sum5days, cloud cover7, T7sum2days

mean effective temperature: 7.4°C, mean equivalent temperature: 18.6°C
= chilly conditions

South wind:

Cases: 18, r^2 = 65%
Predictors: Teff14-1day, Teq14-2days

mean effective temperature: 11.4°C, mean equivalent temperature: 25.4°C
= chilly conditions



Summer

South wind:

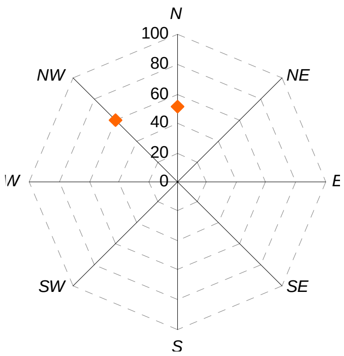
Cases: 15, r^2 = 91%
Predictors: Tmin, Tmin-1day, T19-1day

mean effective temperature: 21.7°C, mean equivalent temperature: 50.6°C
= slightly sultry

South West wind:

Cases: 37, r^2 = 66%
Predictors: Teq14sum4days, Tdp19sum2days, air pressure14, vapour pressure19

mean effective temperature: 21.6°C, mean equivalent temperature: 50.6°C
= slightly sultry



Fall

North wind:

Cases: 23, r^2 = 51%
Predictors: Teq7sum7days, Tmin sum3days

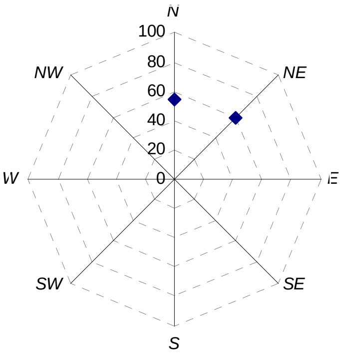
mean effective temperature: 7.9°C, mean equivalent temperature: 21.4°C
= chilly conditions

North West wind:

Cases: 83, r^2 = 59%
Predictors: Tdp7sum7days, Tdp7sum2days, Teq14sum7days, air pressure14, vapour pressure19, T14, T14sum3days, Tdp7-2day, relative humidity, Teff7sum4days

mean effective temperature: 10°C, mean equivalent temperature: 24.3°C
= chilly conditions

Figure 5: High correlations (r^2 > 50%) between different meteorological conditions and total mortality within the classification variable: synoptic categories - seasons



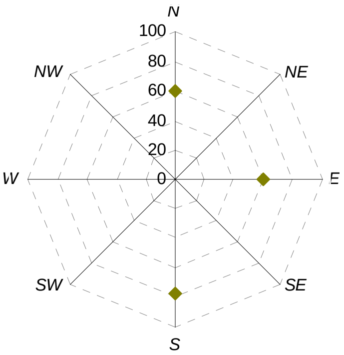
Winter

North wind:
Cases: 35, $r^2 = 54\%$
Predictors: Tdp7sum6days, Tdp7-2days, Teff19-3days

mean effective temperature: 2.1°C, mean equivalent temperature: 9.3°C
= chilly conditions

North East wind:
Cases: 31, $r^2 = 58\%$
Predictors: Tdp7sum3days, sunshine duration, relative humidity, Tdp7sum4days

mean effective temperature: 3.5°C, mean equivalent temperature: 6.5°C
= chilly conditions



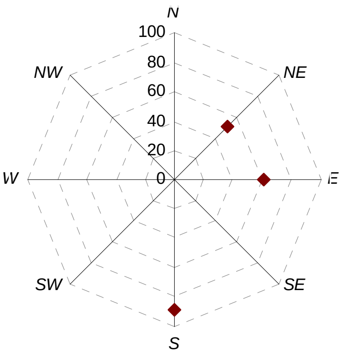
Spring

North wind:
Cases: 46, $r^2 = 60\%$
Predictors: air pressure19, Tdp14sum2days, Tdp19-1day, Tdp19, cloud cover19, Tdp7sum4days

mean effective temperature: 7.2°C, mean equivalent temperature: 17.4°C
= chilly conditions

East wind:
Cases: 35, $r^2 = 60\%$
Predictors: Teff14sum5days, Tmin sum7days

South wind:
Cases: 18, $r^2 = 77\%$
Predictors: Teff14-1day, Teq14, Tdp7sum7days



Summer

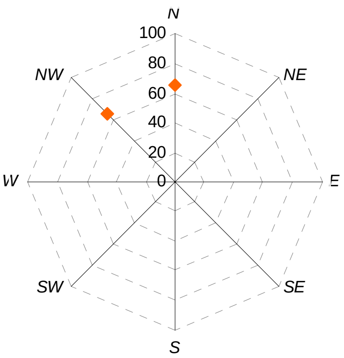
North East wind:
Cases: 46, $r^2 = 52\%$
Predictors: rel.humidity14, Tdp19sum6days, Tmin, Tmax-1day

mean effective temperature: 17.2°C, mean equivalent temperature: 41.5°C
= comfortable

East wind:
Cases: 27, $r^2 = 61\%$
Predictors: T19-3days, Tmax sum7days, Teff14sum6days, cloud cover14

mean effective temperature: 18.6°C, mean equivalent temperature: 44.6°C
= comfortable

South wind:
Cases: 15, $r^2 = 89\%$
Predictors: Tmin, air pressure7, T7-3days



Fall

North wind:
Cases: 23, $r^2 = 65\%$
Predictors: Tdp19-3days

***North West wind*:**
Cases: 83, $r^2 = 65\%$
Predictors: Tdp7sum2days, vapour pressure19, Tdp7sum6days, Teq19sum6days, cloud cover14, Tdp7-2days, Teq19, Teq7-3days, T19sum4days, Teff19sum5days

Figure 6: High correlations ($r^2 > 50\%$) between different meteorological conditions and mortality > 74 years old within the classification variable: synoptic categories – seasons

5. ACKNOWLEDGMENTS

Many thanks to Reinhold Steinacker and Markus Ristic from Institute of Meteorology, University of Vienna, for providing typical examples of R. Steinacker's synoptic classification.

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