SYNOPTIC CLIMATOLOGICAL CATEGORIZATION AND HUMAN MORTALITY IN SHANGHAI, CHINA

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ABSTRACT: This paper shows the synoptic climatological categorization for winter and summer in Shanghai, China by means of principal components analysis and clustering analysis. We objectively provide distinctions of the twenty-one major synoptic categories in winter and the eight major synoptic categories in summer, including main categories and subcategories. In addition, this paper points out the relationships between the synoptic categories and human mortality. Usually, the colder the weather in winter or the hotter the weather in summer, the more the mortality. But the relationships in summer are stronger than those in winter. The subcategories 12(hot) & 15(very hot) in summer are very dangerous to human beings. Especially, the eleven of all 12-day of the subcategory 15 appear in the top 50 mortality days.

INTRODUCTION

One of the important goals of climatology is the rational categorization of weather systems(Davis and Kalkstein,1990). The synoptic climatological index is a very good procedure to achieve this goal. It is very useful to use a synoptic categorization that accentuates homogeneity in weather type to evaluate environmental factors such as human mortality, pollution concentration, and to study the regional climate.

There are two purposes in this paper. The first purpose is to combine individual weather elements into groups that are representative of the different characteristic of weather. The second one is to evaluate the relationships between the human mortality and the synoptic index.

PROCEDURE

The temporal synoptic index(TSI) assigns each day to a particular synoptic category based primarily on air mass differentiation(Kalkstein et al.1987). This is accomplished by defining each day in terms of ten meteorological elements, which include:

1. air temperature(°c)
2. relative humidity(%)
3. air pressure(mb)
4. wind speed(m/sec.)
5. wind direction(azimuth)
6. total cloud cover(tenths of sky cover)
7. maximum temperature(°c)
8. minimum temperature(°c)
9. precipitation(mm)
10. sunshine-hour(hour).

The two wind variables are converted to a south scalar(vv), and a west scalar(uu), where vv is the negative product of the cosine of the wind direction and the wind speed, and uu is the negative product of the sine of the wind direction and the wind speed.

The first six meteorological elements are measured four times daily to permit the evaluation of diurnal effects(0200,0800,1400,2000 LST). The other four meteorological elements are measured one time daily. So, each day is defined by 28 total variables that represent the basis for categorization.

Meteorological data for 30 winter months from December 1979 through February 1989 and for 30 summer months from June 1980 through August 1989 and mortality in the same period were collected for Shanghai, China.

First, we developed TSI by means of statistical methods. The principal components analysis was performed to reduce a large number of intercorrelated weather variables to a smaller number of uncorrelated principal component variables which explain much of the variance within the original data set. The number of principal components to be retained was determined to calculate the component scores. Then, we generated clustering diagnostics and provided an appropriate number of clusters. If some clusters were very large, they were nested to get an appropriate number of subcategories.

Second, we demonstrated the relationships between human mortality and synoptic categories. The top 50 mortality days and the bottom 50 mortality days were sorted respectively to obtain information about which synoptic categories are dangerous to human beings.

Finally, we did stepwise multiple regression. There are 30 independent variables which included not only above 28 weather variables but the consecutive days and the time of season. If a synoptic category appears on a few consecutive days, the variable of the consecutive days is equal to 1 on the first day and 2 on the second day, and so on. The variable of the time of season equals to 1 on the first day of each season in each year, such as the 1st of December(winter), the 1st of June(summer), and it equals to 92 on the last day of summer(the 31st of August) in each year, 91 on the last day of winter in leap years(the 29th of February), 90 on the last day of winter in other years(the 28th of February). In addition, only mortality is a dependant variable.

RESULTS

RESULTS from the SYNOPTIC INDEX

Principal components analysis on 28 weather variables for 903 winter days and 920 summer days respectively resulted in a six-component solution and a four-component solution explaining 79.28% and 64.39% of the variance in the raw data set(Table 1 and Table 2).

Table 1. Principal components loadings for Shanghai, China six component solution (winter)

Variable[a]	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6
Ta 0200	0.78	-0.17	0.27	0.45	0.02	-0.06
Ta 0800	0.87	-0.10	0.10	0.40	0.01	-0.10
Ta 1400	0.66	0.63	-0.02	0.29	0.13	-0.10
Ta 2000	0.83	0.33	-0.10	0.25	0.08	-0.18
Hu 0200	0.56	0.00	0.14	-0.29	0.63	0.06
Hu 0800	0.59	0.07	0.11	-0.38	0.59	-0.01
Hu 1400	0.60	-0.64	-0.01	-0.28	0.09	-0.05
Hu 2000	0.70	-0.19	-0.19	-0.37	0.15	-0.02
Pr 0200	-0.76	-0.10	-0.46	0.02	0.16	-0.27
Pr 0800	-0.82	-0.17	-0.36	0.13	0.23	-0.24
Pr 1400	-0.82	-0.29	-0.23	0.20	0.28	-0.21
Pr 2000	-0.77	-0.35	-0.07	0.26	0.31	-0.20
uu 0200	-0.51	0.08	0.53	-0.13	0.15	-0.17
uu 0800	-0.46	0.10	0.70	-0.10	0.09	-0.20
uu 1400	-0.32	0.16	0.79	-0.15	-0.09	-0.20
uu 2000	-0.14	-0.05	0.70	-0.19	-0.22	-0.26
vv 0200	0.37	0.59	-0.02	-0.22	0.02	-0.23
vv 0800	0.25	0.69	-0.14	-0.31	-0.09	-0.29
vv 1400	0.34	0.56	-0.45	-0.28	-0.16	-0.25
vv 2000	0.04	0.57	-0.34	-0.33	-0.24	-0.14
Cl 0200	0.29	-0.64	0.08	0.03	-0.19	-0.08
Cl 0800	0.42	-0.66	-0.02	-0.08	-0.11	-0.26
Cl 1400	0.34	-0.72	-0.17	-0.13	-0.08	-0.26
Cl 2000	0.39	-0.55	-0.19	-0.09	-0.10	-0.14
MaxTa	0.69	0.56	0.07	0.33	0.12	-0.08
MinTa	0.83	-0.18	0.15	0.40	0.00	-0.11
Rainfall	0.34	-0.40	0.07	-0.31	0.01	0.43
Sunshine	-0.46	0.77	0.04	0.14	0.09	0.25
Eigenvalue	9.46	5.52	2.89	1.92	1.32	1.09
Exp. var.[b]	33.79	19.71	10.32	6.86	4.71	3.89
Cum.exp.var.[c]	33.79	53.50	63.82	70.68	75.39	79.28

Note: a: Key to variables is as follows. Ta: air temperature; Hu: humidity; Pr: pressure; uu: west wind scalar; vv: south wind scalar; Cl: cloud cover; MaxTa: daily maximum air temperature; MinTa: daily minimum air temperature.
b: Explained variance of each component (%)
c: Cumulative explained variance (%)

Air temperature (including maximum temperature and minimum temperature) and relative humidity in both seasons, emphasizing the thermal/moisture variations in the data, were highly correlated with component 1. The uu wind variables in the both seasons loaded highly on component 3. Cloud cover and sunshine variables were important in component 1 in summer and in component 2 in winter. The pressure variables dominated the loadings for component 1 in winter and component 2 in summer. The vv wind variables were important in component 2 in winter and in component 3 & 4 in summer. A moderately strong positive loading in winter and a moderately strong negative loading for rainfall variables in summer were apparent in component 6 and component 1 & 2 respectively.

Table 2. Principal components loadings for Shanghai, China four component solution (summer)

Variable[a]	Comp.1	Comp.2	Comp.3	Comp.4
Ta 0200	0.68	-0.48	-0.23	-0.20
Ta 0800	0.84	-0.29	-0.21	-0.16
Ta 1400	0.93	-0.07	-0.04	-0.03
Ta 2000	0.85	-0.26	-0.15	-0.09
Hu 0200	-0.25	-0.22	-0.24	0.17
Hu 0800	-0.55	-0.42	-0.33	0.13
Hu 1400	-0.61	-0.49	-0.43	-0.01
Hu 2000	-0.41	-0.40	-0.56	0.10
Pr 0200	-0.17	0.83	-0.14	0.11
Pr 0800	-0.16	0.87	-0.07	0.13
Pr 1400	-0.23	0.84	-0.03	0.13
Pr 2000	-0.23	0.79	0.06	0.15
uu 0200	0.08	-0.18	0.65	0.39
uu 0800	0.27	-0.34	0.61	0.48
uu 1400	0.29	-0.40	0.46	0.58
uu 2000	0.10	-0.43	0.42	0.47
vv 0200	0.44	0.07	-0.44	0.44
vv 0800	0.47	0.15	-0.54	0.48
vv 1400	0.35	0.27	-0.55	0.45
vv 2000	0.34	0.24	-0.42	0.53
Cl 0200	-0.53	-0.32	-0.01	0.14
Cl 0800	-0.58	-0.34	-0.16	0.08
Cl 1400	-0.54	-0.38	-0.12	0.03
Cl 2000	-0.43	-0.36	-0.14	0.21
MaxTa	0.93	-0.14	-0.04	-0.03
MinTa	0.72	-0.42	-0.28	-0.21
Rainfall	-0.35	-0.35	-0.17	0.15
Sunshine	0.77	0.42	0.10	-0.09
Eigenvalue	7.84	5.44	3.14	1.61
Exp. var.[b]	28.00	19.43	11.21	5.75
Cum.exp.var.[c]	28.00	47.43	58.64	64.39

(Note as Table 1.)

Numerous synoptic categories in winter (Table 3) and in summer (Table 4) were uncovered for the period of record. Four and three major synoptic categories(a major category is defined as consisting of 10 or more days) were noted for winter and for summer respectively. A brief discussion of the character of each major synoptic category for Shanghai, China follows.

First, the character of each major main synoptic category in winter is discussed. Cluster 1 is defined as the prelude of a cold wave. Usually, over Eastern China in winter, before a cold wave comes, it is not too cold and it is frequently rainy. Cluster 2 clearly represents the character of a clear air mass. The cloud cover is the least of all the synoptic categories. Cluster 3 identifies a very cold class controlled by cold anticyclone, or a cold wave category, which the temperature is the lowest. Cluster 4 presents a warm and rainy group with the highest temperature and the most precipitation in the major categories. In addition, the four clusters usually appear cyclically in order of 1, 3, 2, 4. These four main clusters were respectively divided into 4, 3, 6, 4 major subcategories.

Table 3. Meteorological character of the winter synoptic categories in Shanghai, China

synoptic category	day	Mean diurnal range: Temp(°c)	Humidity(%)	Pressure(mb)	Cloud(tiths)	Wind[a]	Mean[b]: MaxT	MinT	Rain	Sun
1 prelude of cold wave	227	4.2/ 6.1	68.5 / 81.5	1026 / 1028	8.6 / 9.7	NNE Li	7.4	2.8	1.7	0.9
11 overcast	76	3.7/ 7.0	68.1 / 82.9	1024 / 1026	7.8 / 9.8	NNW Li	7.6	2.5	0.7	0.7
12 rain	59	3.6/ 4.9	75.7 / 84.2	1026 / 1028	9.3 / 9.9	NNE Mo	6.6	2.7	4.1	0.5
13 cloudy	64	4.6/ 7.3	59.4 / 73.8	1029 / 1030	8.0 / 9.3	NE Li	8.0	3.4	0.3	1.7
14 cold front departing	28	3.2/ 4.7	73.8 / 80.9	1024 / 1028	8.6 / 9.9	NW Li	7.0	2.3	3.1	0.4
2 clear	336	2.2/10.3	44.5 / 84.0	1024 / 1027	2.5 / 2.9	NE Vl	10.9	0.4	0.1	7.3
21 dry and cold	34	-1.0/ 5.9	33.1 / 74.8	1026 / 1030	0.3 / 1.0	WNW Li	6.6	-3.4	0.0	8.5
22 mild	39	5.0/13.7	51.5 / 87.8	1021 / 1022	3.8 / 4.7	W Vl	14.3	4.0	0.1	5.9
23 some maritime influence	79	3.1/13.6	45.7 / 90.0	1022 / 1025	1.3 / 2.7	SSE Li	14.1	1.4	0.0	7.7
24 continental influence	38	2.7/10.4	33.5 / 73.9	1024 / 1026	0.2 / 1.8	WNW Mo	11.0	1.0	0.0	8.5
25 sunny	115	0.0/ 8.5	47.0 / 84.4	1028 / 1030	2.5 / 4.5	ENE Li	9.1	-0.9	0.0	7.0
26 partly cloudy	30	3.7/ 8.8	55.1 / 88.0	1024 / 1028	2.3 / 6.0	NW Li	9.4	2.7	0.5	6.0
3 anticyclone control (very cold)	104	-0.6/ 3.7	43.8 / 68.2	1030 / 1032	4.1 / 4.9	SE Li	4.7	-1.6	0.1	6.1
31 partly cloudy	105	0.3/ 5.0	44.7 / 72.0	1030 / 1032	4.2 / 5.9	NNW Li	5.7	-0.7	0.1	5.9
32 Siberian cold current	52	-2.5/ 2.3	33.7 / 64.3	1031 / 1033	1.0 / 2.5	NW Mo	3.4	-3.3	0.0	8.4
33 very cold	21	-0.3/ 1.2	64.8 / 68.8	1031 / 1032	7.4 / 9.9	SSW Mo	2.7	-1.5	0.7	1.0
4 warm and rain	137	8.0/10.6	78.7 / 88.7	1018 / 1020	8.3 / 9.4	NE Li	11.7	6.3	4.0	0.9
41 cyclone passage	30	6.4/ 7.9	89.7 / 98.7	1017 / 1020	9.6 / 10	NE to N	9.2	5.6	9.1	0.0
42 very warm	44	9.2/12.2	74.0 / 87.0	1020 / 1022	8.1 / 9.2	NE Li	13.3	7.9	1.3	1.1
43 weaker cyclonic influence	30	7.9/13.4	74.6 / 89.7	1014 / 1018	7.5 / 9.1	SE Li	14.0	6.6	3.1	2.0
44 maritime influence	16	4.4/ 8.3	77.2 / 87.7	1022 / 1026	6.8 / 9.9	E Mo	8.9	3.5	2.3	0.8

Note: a: Wind: wind direction and speed; Vl: very light(V < 2.0 m/s); Li: light(2.0 m/s < V < 4.0 m/s); Mo: moderate(4.0 m/s < V < 6.0 m/s); St: strong(V > 6.0 m/s).
b: MaxT: maximum air temperature(°c);MinT:minimum air temperature(°c); Rain: rainfall(mm); Sun: sunshine(hours).

Second, we discuss the character of each major synoptic category in summer. Cluster 1 is a dominant cluster controlled by subtropical anticyclone. It is divided into 5 subcategories in which two of categories respectively were a hot(12) and a very hot(15). Cluster 2 is defined as

Table 4. Meteorological character of the summer synoptic categories in Shanghai, China

synoptic category	day	Mean diurnal range: Temp(°c)	Humidity(%)	Pressure(mb)	Cloud(tiths)	wind[a]	Mean[b]: MaxT	MinT	Rain	Sun
1 subtropical anticyclone control	862	24.4/26.0	78.0 / 90.9	1005 / 1006	5.1 / 7.5	SE Vl	30.0	23.5	5.1	6.0
11 cloudy	145	28.0/28.6	68.0 / 88.4	1009 / 1010	6.1 / 7.6	ESE Li	27.4	20.0	0.7	6.4
12 hot	479	25.9/31.4	65.4 / 90.5	1004 / 1005	4.8 / 7.0	ESE Vl	32.4	25.0	3.3	7.9
13 thunderstorm	185	22.5/24.5	85.0 / 98.3	1006 / 1008	9.4 / 10	E Vl	28.7	21.5	13.0	0.7
14 windy	46	23.6/28.7	78.1 / 91.2	1005 / 1006	6.5 / 9.3	E Mo	28.7	24.8	4.7	5.7
15 very hot	12	27.7/36.7	58.9 / 88.4	1004 / 1008	2.8 / 6.7	WSW Li	35.7	27.7	0.0	12.0
2 typhoon	22	24.0/26.1	88.4 / 92.2	997 / 998	7.4 / 9.8	WNW Li	27.6	23.4	23.0	2.1
3 sunny and hot	30	20.6/27.9	44.8 / 81.8	1008 / 1009	3.0 / 4.9	NW to NE	28.6	19.3	0.6	9.8

(Note as the same Table 3)

typhoon with the lowest air pressure and more rainfall. Cluster 3 possesses a sunny and hot regime with the least cloud cover, the least relative humidity, and little precipitation.

RESULTS from the RELATIONSHIPS between MORTALITY and SYNOPTIC CATEGORIES

The relationships between mortality and synoptic categories were showed in Table 5. From Table 5, the most daily average mortality in winter was in the cluster 3 (163), because the cluster 3 was a very cold synoptic category. And the most daily average mortality in summer was in the cluster 1 (103). Two of the most daily average mortality in summer were in the subcategories 12 & 15 (103 & 161) because it was very hot, long duration of sunshine, little cloudiness, no rain or little rain, and low wind speed in both subcategories. It was important that the lag of death was one day to the synoptic categories in winter.

Table 5. Daily average mortality in synoptic categories in Shanghai, China

Winter		Summer		Summer	
category	mortality	category	mortality	subcategory	mortality
1 prelude of cold wave	147	1 subtropical anticyclonic influence	103	11 cloudy	98
2 clear	147	2 typhoon	94	12 hot	103
3 anticyclonic control (very cold)	156	3 sunny and hot	99	13 thunderstorm	93
4 warm and rain	140			14 windy	94
				15 very hot	161

In addition, the frequency in top 50 mortality days of the cluster 3 in winter were 17, while that in the bottom 50 mortality days were only 5. Subcategories 15 & 12 in summer appeared in all of the top 50 mortality days. The eleven of all 12-day of the subcategory 15 in summer were in the top 50 mortality days. And 39-day of the subcategory 12 in summer were in the top 50 mortality days, while 16-day of this category were in the bottom 50 mortality days.

So, subcategories 15 & 12 in summer and category 3 in winter,especially subcategory 15, are very dangerous to human beings.

RESULTS from the REGRESSION ANALYSIS

We chose three categories with the most mortality to do the stepwise multiple regression analysis with 0.05 level. In winter, the relationships between individual weather variables and human mortality for the category 3 were very weak(model $R^2=0.074$). The regression equation is:

$$Mort(3) = 159.81 - 3.08Ta_{20}$$

In summer, the relationships between individual weather variables and human mortality for the subcategory 12 and the subcategory 15 with model $R^2=0.34$ and

0.46 respectively were moderately strong. The regression equations respectively are:

$$Mort(12) = -943.78 + 1.9Ta_{02} - 0.56Hu_{14} + 0.88Pr_{02} + 2.03uu_{02} + 5.03MaxTa - 1.17Sunshine$$

$$Mort(15) = 208.99 - 19.58uu_{08}$$

The relationships between synoptic categories and mortality in summer are stronger than those in winter because the heating apparatus is used commonly in winter, while few air-conditioners are used in summer in Shanghai.

CONCLUSIONS

It is apparent that the synoptic index provides very useful information about the synoptic climatological category and the relationships between weather and human mortality. This paper provided following several results. (1) The procedure objectively identified distinctions of three major synoptic categories with five subcategories for the cluster 1 in summer and four major synoptic categories with four, six, three, and four subcategories respectively. (2) The synoptic categories 3 in winter and 12 & 15 in summer are dangerous to human beings. Especially, the eleven of the all 12-day of the subcategory 15 appeared in top 50 mortality days. (3) The four clusters in winter usually appear cyclically in order of 1,3,2,4 in Shanghai.

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