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Classification of Weather Patterns over the East Asia Region using the Clustering Analysis

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Introduction

Medium-range forecast is highly dependent on ensemble forecast data. However, operational weather forecasters have not enough time to digest all of detailed features revealed in ensemble forecast data. To utilize the ensemble data effectively in medium-range forecasting, representative weather patterns in East Asia in this study are defined.

Data and Method

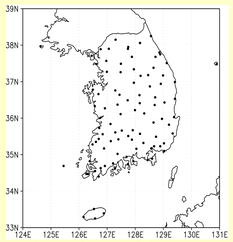

Fig. 1. Locations of 95 Automated Synoptic Observing Systems (ASOSs) over South Korea.

The k-means clustering analysis is applied for the objectivity of weather patterns. Input data used daily Mean Sea Level Pressure (MSLP) anomaly of the ECMWF ReAnalysis-Interim (ERA-Interim) during 1981 ~ 2010 (30 years) provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). Additionally, we investigate the relationship between weather patterns and extreme weather events such as heat wave, cold wave, and heavy rainfall as well as snowfall.

Table. 1. The information of dataset used in this study.

Dataset	Period	Variables	Spatial resolution
ERA-Interim	1981-2010	Daily Mean Sea Level Pressure (MSLP)	1.5 degree
ASOS		Daily precipitation Maximum fresh snow depth Daily maximum and minimum temperature	-

Optimal Domain Size

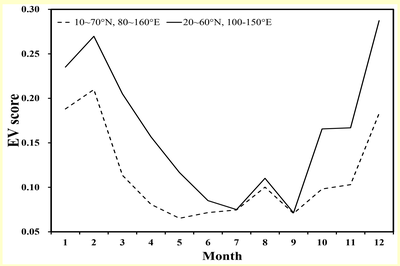

Fig. 2. Comparison of EV score between wide area (10~70°N, 80~160°E) and narrow area (20~60°N, 100~150°E).

Using the EV (Explained Variation) value, selects the optimal region that best describes the temperature of South Korea (7 Stations)

$$EV = \frac{\sum_{k=1}^{K} N_k(\bar{a}_k - \bar{a})^2}{\sum_{i=1}^{N}(a_i - \bar{a})^2}$$

N is the number of cases, K is the number of weather patterns, a_i is the value (temperature) of the target for case i. The higher the values of EV, the better is the discrimination of a classification for the atmospheric variables.

Number of Cluster

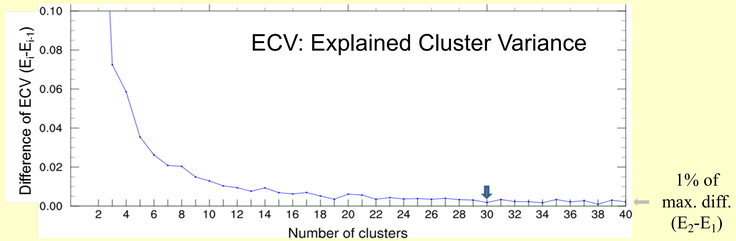

Fig. 3. Difference of ECV (Ei-Ei-1) on the number of cluster.

$$\mathbf{WSS} = \sum_{k=1}^{k=n} \sum_{i=1}^{i=nk} (x_{ki} - c_k)^2$$

$$\mathbf{ECV} = 1 - \frac{wss}{tss}$$

k is the number of clusters,
i is the object number,
c is the centroid of each cluster

The degree of dissimilarity within the resulting clusters can be measured by within cluster sum of squares (WSS) values.

The quality of a classification result is reflected by the ratio of the WSS and the total sum of squares (TSS)

Weather Patterns over East Asia

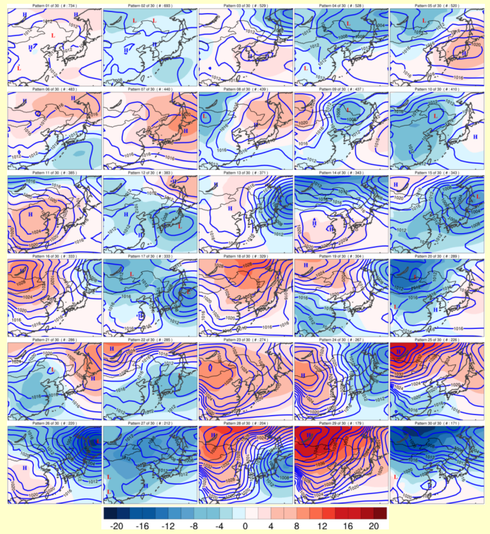

Fig. 4. Weather patterns over the East Asia region. Contour line and Shaded indicate MSLP and MSLP anomaly, respectively.

Table. 2. Characteristics of 30 weather patterns over East Asia region.

	Descriptions
1	Weak South-Westerly
2	Weak North-Westerly
3	Anticyclonic
4	Cyclonic South-Westerly
5	Southerly, high of Japan
6	Unbiased North-Easterly
7	Anticyclonic, high N of Japan
8	North-Easterly, high N of Korea
9	Cyclonic Westerly, low N of Korea
10	Cyclonic South-Westerly, low N of Korea
11	Anticyclonic North-Westerly, high of China
12	Cyclonic North-Westerly, low of Japan
13	Unbiased Northerly, low NE of Japan
14	North-Westerly, high of China
15	Cyclonic Northerly, low NE of Japan
16	Northerly, high of Siberia
17	Cyclonic North-Westerly, low E of Japan
18	Anticyclonic Northerly, high N of Korea
19	Unbiased Easterly
20	Westerly, low of Mongoria
21	Cyclonic Southerly
22	Cyclonic North-Westerly
23	Anticlyclonic North-Westerly, high of Mongolia
24	Northerly, high and low in West and East
25	Easterly, high of Siberia
26	Cyclonic North-Westerly, Deep low NE of Japan
27	Cyclonic Westerly
28	Northerly, high and low in Siberia and Japan
29	Anticyclonic North-Easterly, deep high of Siberia
30	Unbiased Westerly

Table. 3. Monthly frequency according to weather pattern (Group Number; GN).

GN	Month 1	2	3	4	5	6	7	8	9	10	11	12	Ave Occ.(%)
1	2.7	2.7	2.6	2.8	5.1	12.3	**15.2**	**18.7**	9.4	4.5	2.8	1.3	6.7
2	1.8	4.5	3.0	3.0	4.6	11.8	**17.3**	10.8	8.3	5.0	2.4	3.2	6.3
3	2.4	2.9	3.4	3.7	6.6	8.9	8.9	7.0	5.6	3.0	2.9	2.7	4.8
4	3.4	2.9	2.7	5.4	4.8	7.3	7.0	7.7	5.7	3.8	4.0	3.0	4.8
5	4.8	2.9	4.3	3.9	5.8	5.4	4.2	2.7	7.4	7.1	4.3	4.0	4.8
6	2.6	1.8	2.6	3.6	6.7	6.4	7.6	7.1	6.6	3.2	3.2	1.4	4.4
7	2.6	4.3	2.9	4.4	4.6	4.3	4.7	5.2	3.2	4.8	3.3	3.8	4.0
8	4.3	3.9	3.9	4.8	4.6	3.8	3.9	2.8	3.2	5.7	4.2	3.0	4.0
9	2.4	3.0	3.1	3.8	5.7	5.8	4.2	5.3	4.3	4.4	2.9	3.0	4.0
10	4.1	4.3	4.6	4.3	3.9	2.4	2.0	4.0	3.4	3.2	4.7	4.0	3.7
11	4.1	4.5	3.9	4.8	3.4	2.6	1.7	2.8	2.9	3.7	4.0	4.0	3.5
12	1.9	2.6	3.2	3.4	4.8	5.2	3.9	3.7	6.6	2.8	1.6	2.3	3.5
13	4.0	4.1	3.1	3.0	3.1	4.0	3.6	3.1	3.0	3.3	3.3	3.1	3.4
14	4.3	3.9	4.6	3.0	2.9	0.7	0.8	1.2	2.1	3.3	6.1	4.7	3.1
15	3.4	3.6	4.3	2.9	3.9	2.2	3.6	2.9	2.6	2.3	3.8	2.3	3.1
16	2.8	2.6	2.8	4.0	2.5	2.6	2.7	2.6	4.3	3.6	2.2	3.9	3.0
17	3.2	2.9	4.3	3.2	3.6	2.4	1.4	1.7	3.0	3.7	3.7	3.4	3.0
18	4.2	3.7	4.5	3.4	2.4	2.2	1.6	1.1	3.0	3.3	3.2	3.4	3.0
19	2.6	2.7	3.3	4.4	2.9	2.3	0.8	1.5	3.3	2.4	3.7	3.4	2.8
20	4.0	5.0	2.7	3.6	1.8	0.4	0.2	0.5	1.2	2.8	4.4	5.2	2.6
21	4.7	2.5	3.2	3.1	2.2	1.2	1.1	1.2	1.1	3.0	3.4	4.5	2.6
22	2.7	2.5	2.6	3.4	3.0	2.0	1.4	1.9	2.1	4.0	3.0	2.6	2.6
23	3.2	4.4	4.4	2.6	1.8	1.8	1.0	2.0	1.8	2.0	1.9	3.2	2.5
24	3.2	3.8	1.7	2.1	3.0	1.0	0.5	1.1	2.0	3.0	3.0	4.8	2.4
25	3.7	3.0	3.8	2.0	1.6	0.2	0.0	0.0	0.8	3.6	3.4	2.8	2.1
26	3.3	1.6	2.6	2.8	2.0	0.3	0.4	0.7	1.4	3.2	3.3	2.4	2.0
27	2.9	3.8	3.9	2.4	1.1	0.2	0.3	0.9	0.9	1.5	2.9	2.6	1.9
28	3.0	3.2	2.6	2.9	0.8	0.0	0.0	0.0	0.4	2.0	2.3	5.2	1.9
29	3.8	3.7	2.5	1.4	0.3	0.0	0.1	0.0	0.1	0.8	4.3	2.8	1.6
30	3.9	2.9	2.9	1.8	0.5	0.0	0.0	0.0	0.1	1.1	1.6	4.1	1.6

30 representative weather patterns with their frequencies are summarized. Weather pattern #1 occurred all seasons, but it was about 56% in summer (June ~ September). The relatively rare occurrence of weather pattern (#30) occurred mainly in winter.

Weather Patterns related to Severe Weather

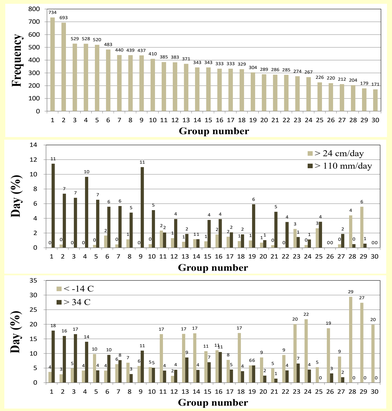

Fig. 5. Frequency (day; upper), day (%) of extreme precipitation (middle) and temperature (bottom) events according to weather pattern. Day (%) is calculated by the ratio of extreme days to total day by weather pattern.

The weather patterns associated with heavy rainfall exceeding 110 mm day-1 were #1, #4, and #9 with days (%) of more than 10%. Heavy snowfall events exceeding 24 cm day-1 mainly occurred in weather pattern #28 (4%) and #29 (6%). High and low temperature events (> 34℃ and < -14℃) were associated with weather pattern #1~4 (14~18%) and #28~29 (27~29%), respectively.

References

Neal, R., Fereday, D., Crocker, R., and Comer, R. E., 2016: A flexible approach to defining weather patterns and their application in weather forecasting over Europe. *Meteorol. Appl.*, **23(3)**, 389-400, doi:10.1002/met.1563.

Acknowledgments

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