Some Aspects of the Persistence Between Fall and Winter Mean Temperatures in Indiana

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Introduction

Accurate predictions of winter mean temperature would be helpful in allocating fuel supplies to meet the anticipated energy demands for heating. While there has been little accuracy in deterministic long-range weather forecasts, persistence of temperature anomalies from one season to the next may provide some help in planning.

The day-to-day continuity of the synoptic weather provides the concept of persistence, which is important in synoptic weather prediction (MacDonald and Shapiro, 1964). Seasonal mean temperatures may or may not demonstrate this kind of persistence, however, because of the longer period involved. van Loon and Jenne (1975) used the persistence between adjacent seasons to estimate seasonal mean temperatures. They found that the highest correlation between two seasons occurred if the first were extremely cold or extremely warm.

The objective of this study is to examine, with correlation-regression methods and with a contingency table approach, the degree of persistence of temperature anomalies from fall to winter, using the climatological division mean temperature for fall and the following winter in Indiana.

Data and Procedures

The fall and the winter mean temperature for nine climatological divisions in Indiana were obtained from the monthly Climatological Data, Indiana (USDC, 1931-1980), from September to February, 1931-1980. The average mean temperatures for the three months, September, October, and November, represent the fall mean temperatures, and the averages of the three months, December, January, and February, the winter mean temperatures.

The divisional mean temperatures were also used to obtain the means for three larger regions and the State. The northern region (NORTH) included the Northwest (NW), North Central (NC) and Northeast (NE) divisions; the central region (CENTRAL) included the West Central (WC), the Central (CC) and East Central (EC) divisions; and the southern region (SOUTH) included the Southwest (SW), South Central (SC) and Southeast (SE) divisions. The state average temperature was computed as the average of the mean temperatures of the nine divisions (equal-weighting).

The correlation coefficient (r) was calculated as $r = \frac{s_{xy}}{s_x s_y}$, where s_{xy} is the covariance of the fall and the winter mean temperatures, and s_x and s_y are the standard deviations of the fall and the winter mean temperatures, respectively. An analysis of variance and an F-test (Panofsky and Brier, 1965, p. 93) was conducted to test the null hypothesis that $r = 0$ (no persistence).

To detemine if there were any temperature trend, the fall and the winter mean temperatures were each regressed on years. To determine the correlation between seasons, the winter mean temperatures were regressed on fall temperatures for each division and region and the State. The simple linear regression model, $Y = b_0 + b_1X$, was used, where Y is the dependent variable and

X is the independent variable, year in the trend analysis and fall mean temperature in the persistence study. Finally, contingency tables of winter on fall mean temperature anomalies were prepared, using three categories determined by plus and minus one-half standard deviation(s) about the respective means.

Results and Discussion

The temperature means and the standard deviations for the fall and the winter seasons for each of the nine divisions, three regions, and the state of Indiana for the period 1931-1980 are shown in Table 1. The covariances between fall and following winter seasons are also shown. The divisional mean temperatures for the fall range from 52.8°F in the NE to 57.4 in the SW, and for the winter from 26.9°F to 33.6.

The fitted regression coefficients for the time trend in fall and winter mean temperatures are shown in Table 2. The trend for the Central division is shown in Figure 1. All divisions showed a cooling trend but that for the Central division was the greatest. Undoubtedly, some of this cooling in Figure 1 can be attributed to changes in time of observation and network configuration, as shown by Nelson *et al.* (1979). This "non-climatic cooling", however, should not affect the persistence of adjacent fall and winter mean temperatures. For all regressions in Table 2 and Figure 1, winter showed a greater cooling trend than fall. The cooling trend for the State is shown as -0.03°F per year in the fall and -0.11°F per year in the winter. The trend regressions were signficant at the $\alpha = 0.10$ level in all divisions except for the NW in the fall. Since the time trends are significant, this may affect the evaluation of the true relationship between fall and winter mean temperatures, because the relation between the two time (or climate) trends may conceal the relation between the two time series. Therefore, the time trend was removed from the published means by subtracting the trend values from the mean temperature, or using departures from a "moving normal". Hereafter, the original mean temperatures will be referred to as "with-trend", and the departures from trend as "without-trend" cases.

TABLE 1. *Fall and the winter mean temperatures (°F), standard deviations, and covariances between fall and winter mean temperatures for 9 divisions, 3 regions and State of Indiana.*

	FALL (1931-1980)		WINTER (1931-1980)		
Division	Mean	Standard deviation	Mean	Standard deviation	Covariance
NW	53.47	2.07	26.87	3.56	1.52
NC	53.00	2.07	27.14	3.59	1.64
NE	52.81	2.08	26.88	3.57	1.97
WC	54.80	2.12	29.44	3.90	2.55
CC	54.36	2.01	29.56	3.92	2.52
EC	53.38	1.99	28.77	3.96	2.19
SW	57.39	2.03	33.64	3.62	1.71
SC	56.42	2.06	33.30	3.66	2.14
SE	56.70	1.96	33.58	3.56	1.74
Region					
NORTH	53.27	2.03	26.96	3.59	1.18
CENTRAL	54.43	1.99	29.33	3.88	1.78
SOUTH	57.09	1.96	33.56	3.68	1.24
State					
INDIANA	54.91	1.97	29.95	3.64	1.37

TABLE 2. *Regression coefficients for trend model, $Y = b_0 + b_1X$, where Y is either fall or winter mean temperature and X is year, r correlation coefficient, and F for testing significance of regression trend for 9 divisions, 3 regions and the State of Indiana.* $F_{1,48;0.90} = 2.82$.

Division	FALL(Y) on YEAR(X) b_0	b_1	r	F	WINTER(Y) on YEAR(X) b_0	b_1	r	F
NW	113.0	-0.031	-0.214	2.304	223.5	-0.101	-0.411	9.756
NC	122.5	-0.036	-0.250	3.200	237.0	-0.107	-0.437	11.330
NE	123.2	-0.036	-0.252	3.255	237.1	-0.108	-0.439	11.459
WC	153.2	-0.050	-0.347	6.571	304.6	-0.141	-0.527	18.457
CC	174.1	-0.061	-0.445	11.852	305.0	-0.141	-0.523	18.073
EC	125.0	-0.037	-0.270	3.774	296.0	0-137	-0.504	16.345
SW	133.6	-0.039	-0.281	4.115	234.5	-0.103	-0.415	9.987
SC	156.1	-0.051	-0.360	7.147	262.1	-0.117	-0.467	13.388
SE	129.0	-0.037	-0.275	3.927	228.1	-0.100	-0.408	9.586
Region								
NORTH	97.1	-0.022	-0.161	1.277	233.6	-0.106	-0.429	10.826
CENTRAL	113.7	-0.030	-0.222	2.488	291.5	-0.134	-0.504	16.345
SOUTH	104.0	-0.024	-0.179	1.589	233.7	-0.102	-0.419	10.221
State								
INDIANA	105.6	-0.026	-0.192	1.837	253.0	-0.114	-0.456	12.601

The correlations between fall and winter mean temperatures, both with- and without-trend, for the nine divisions, three regions and the State of Indiana are shown in Table 3. The r values are comparable to those of van Loon and Jenne (1975). The F values included in Table 3 for the "with-trend" case show that correlation of the fall and the winter mean temperatures are significant at the $\alpha = 0.10$ level for the Northeast, West Central, Central, East Central, South Central and Southeast divisions. Although these r values are not very high, they are all positive, suggesting some degree of persistence. In fact, 4% to 10% (r^2)

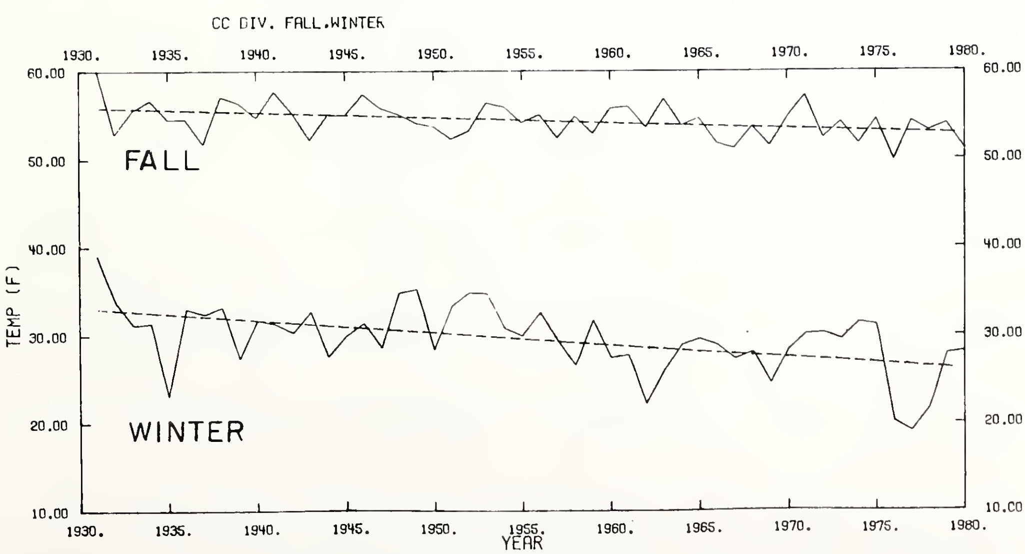

FIGURE 1. *Mean temperatures for fall and winter on years and linear trends (dashed lines) for the Central (CC) climatological division, Indiana, 1931-1980.*

TABLE 3. *Regression coefficients for model, $Y = b_0 + b_1X$ where Y is winter mean temperature and X is preceding fall mean temperature, correlation coefficient, and F value, with-and without-trend, for 9 divisions, 3 regions and the State of Indiana.* $F_{1,48;0.90} = 2.82$.

Division	WITH-TREND WINTER(Y) on FALL(X) b_0	b_1	r	F	WITHOUT-TREND WINTER(Y) on FALL(X) b_0	b_1	r	F
NW	7.990	0.353	0.206	2.127	0.018	0.212	0.132	0.851
NC	6.917	0.381	0.220	2.441	0.002	0.203	0.127	0.787
NE	2.842	0.455	0.265	3.625	-0.004	0.285	0.179	1.594
WC	-1.757	0.569	0.309	5.067	-0.001	0.260	0.157	1.197
CC	-4.429	0.625	0.320	5.476	0.000	0.213	0.115	0.639
EC	-0.617	0.551	0.279	4.052	0.000	0.296	0.165	1.348
SW	9.434	0.422	0.234	2.781	0.004	0.229	0.135	0.895
SC	5.089	0.500	0.284	4.211	0.000	0.230	0.138	0.930
SE	7.685	0.457	0.249	3.173	0.030	0.273	0.158	1.234
Region								
NORTH	11.641	0.288	0.162	1.294	0.002	0.167	0.103	0.516
CENTRAL	4.952	0.448	0.230	2.681	-0.001	0.239	0.138	0.928
SOUTH	15.048	0.324	0.178	1.571	-0.006	0.194	0.116	0.652
State								
INDIANA	10.561	0.353	0.191	1.817	0.000	0.202	0.121	0.708

of the variance in the winter mean temperatures is associated with the previous fall mean temperatures. However, when the trend effect is removed, none of the regressions are significant, and only 1% to 3% of the winter mean temperature variance is associated with fall temperatures. Only the fall-winter relationships of the Central division are presented in Figure 2, because of the similarity of

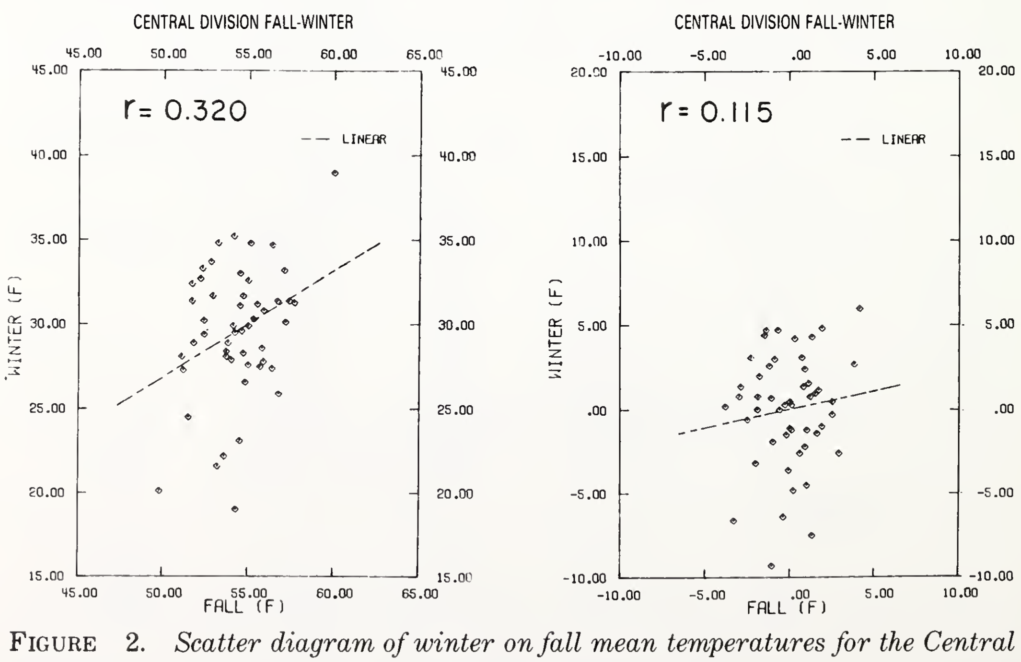

FIGURE 2. *Scatter diagram of winter on fall mean temperatures for the Central (CC) division for 1931-1980, and linear regression (dashed line), with-trend (left), and without-trend (right).*

the other data sets. The scatter diagrams show the reduction in the b_1 and r values from the with-trend to without-trend cases.

The contingency tables for the Central division fall and winter temperature quantiles for both with-trend and without-trend cases are shown in Table 4. For example, for the with-trend case, when the fall mean temperatures averaged below normal (less than $\overline{x}$ - 0.5s). two of the following winters also averaged below normal, six near normal and five above normal. The x^2 value was computed as $x^2 = \frac{(2-2.1)^2}{2.1} + \frac{(6-7.1)^2}{7.1} + \ldots \frac{(3-3.9)^2}{3.9} = 2.80$ which is tested against $x^2_{.10}$ with 4 degrees of freedom. The computed Chi-square values for each division, region and State are shown. It is concluded that the null hypothesis (that fall and winter mean temperatures are independent) can not be rejected, especially for the without-trend cases. This is consistent with findings using the correlation-regression method.

TABLE 4. *Contingency tables for winter on fall mean temperature anomalies for Central division and Chi-square values from similar contingency tables for nine devisions, 3 regions and the State of Indiana, with and without-trend. Values in the parentheses are expected frequencies.*
$\chi^2_{4;0.90}$ = *7.78. B: below mean ($\bar{x}$) – ½ standard deviation (s_x);*
N: between $\bar{x}$ – ½ s_x and $\bar{x}$ + ½ s_x; A: above $\bar{x}$ + ½ s_x; and
T: total number of occurrences.

		WITH-TREND WINTER						WITHOUT-TREND WINTER			
		B	N	A	T			B	N	A	T
	B	2	6	5	13		B	4	7	6	17
F		(2.1)	(7.3)	(3.6)		F		(4.1)	(3.6)	(4.3)	
A	N	5	12	6	23	A	N	4	8	3	15
		(3.7)	(12.3)	(6.4)				(8.2)	(7.2)	(8.6)	
L	A	1	10	3	14	L	A	4	9	5	18
L		(2.2)	(7.8)	(3.9)		L		(4.8)	(4.2)	(5.0)	
	T	8	28	14	50		T	12	24	14	50

Division	Chi-square value	Division	Chi-square value
NW	1.95	NW	0.71
NC	0.35	NC	0.20
NE	3.26	NE	0.96
WC	1.54	WC	0.08
CC	2.80	CC	0.19
EC	3.39	EC	0.36
SW	3.57	SW	0.13
SC	2.83	SC	0.22
SE	5.53	SE	0.55
Region			
NORTH	3.92	NORTH	0.64
CENTRAL	0.70	CENTRAL	0.06
SOUTH	2.50	SOUTH	0.21
State			
INDIANA	2.75	INDIANA	0.18

Summary

The persistence between fall and winter mean temperatures is not significantly high in Indiana. The trend analysis shows climatic cooling, with winter cooling more than fall. The "without-trend" analysis is believed to be a more representative evaluation of the persistence effect, since the existence of trend in both data sets conceals the true persistence relationship.

The fact that all correlations between fall and winter are positive indicates some persistence between fall and the winter mean temperatures in Indiana, but the correlation is too low to rely on persistence of temperature anomalies from fall to predict winter mean temperature. With the cooling trends in both time series, correlation of the published data, instead of the departures from trend, probably adds to the measure of persistence. It is suggested that for the short climatological records (≤ 50 years) departures from trend should be used to obtain a more realistic evaluation of the temperature persistence between adjacent seasons.

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