ON THE USE OF PERSISTENCE TO MODULATE MOS PoP FORECASTS

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ABSTRACT

The persistencies of rain and of no rain into a forecast period from the prior period are shown to be functions of the probabilities of rain in the two periods. These probabilities are taken to be their MOS PoP forecasts. The persistence effect is to modulate the MOS POP for the forecast period to a higher or lower value depending on what occurs in the prior period. Results are presented by graphs, and may be considered a disciplined strategy that gives a forecaster the when, the how, and the how much that MOS PoP forecasts are modulated by persistence.

1. INTRODUCTION

The great empirical study of the effects of persistence on climatological probabilities is ESSA Technical Memorandum WBTM TDL 31 (2). The effects are determined by actual counts with 15 years of the data. The report considers two adjacent 6-hour periods and two adjacent 12-hour periods.

The scheme described here is an effort to determine the effects of persistence on model output statistics probability of precipitation forecasts (MOS PoPs) for two adjacent 6-hour periods and two adjacent 12-hour periods. MOS PoPs can change greatly from one period to the next, so the scheme must handle any combination of adjacent period frequencies. This situation is considerably different than the method in TDL 31, wherein most climatological frequencies are equal and each is less than 50%.

TDL 31 and its nomenclature:

00 hours 04 * / 00 hours 10 Forecaster Position	06 hours 12 hours / 12 hours 24 hours	
Conditional Period Prob. = Climate	Verifying period Prob. = Climate	
If "Wet"	Prob. modulated by persistence to a higher value	WI for 6-hour prds; W2 for 12-hour prds.
If "Dry"	Prob. modulated by persistence to a lower value	DI for 6-hour prds; D2 for 12-hour prds.
This scheme and its nomenclature:		
Prior Period. * Prob. = Its latest MOS Pop	Forecast period Prob. = Its latest MOS Pop	
If "RIPP"	MOS PoP modulated by persistence to a higher value	From Graphs 1 and 3
If "NIPP"	MOS PoP modulated by persistence to a lower value	From Graphs 2 and 4

TDL-31's "Wet" is same as scheme's "RIPP" (Rain In Prior Period)
*TDL-31's "Dry" is same as scheme's "NIPP" (No rain In Prior Period)
*=Forecaster position on top time scales.

Table 1. In two adjacent periods there are four possible events:

1st Period	2nd Period
Rain	Rain
Rain	No Rain
No Rain	Rain
No Rain	No Rain

If the frequencies of rain are expressed in percent, the rain values in Table 2 become rain counts per 100 cases.

Table 2.

Event	1st Period	2nd Period
Rain - Rain	Ra	Ra
Rain - No Rain	Rb	
No Rain - No Rain		Rc

Frequencies:
1st = Ra + Rb
2nd = Ra + Rc

Contract to a two-events table (Rain Counts only), resulting in Table 3:

Table 3.

Event	1st Period	2nd Period	
Rain in 1st.	(Ra + Rb)	Ra	Probability of Rain in 2nd following Rain in 1st: $= \frac{Ra}{Ra + Rb}$
No Rain in 1st.	100 - (Ra + Rb)	Rc	Probability of Rain in 2nd following No Rain in 1st: $= \frac{Rc}{100 - (Ra + Rb)}$

Ra: rain occurs in both periods.
Rb: rain occurs only in first period
Rc: rain occurs only in second period

Above it is shown that, if we can get the rain counts Ra, Rb, and Rc, we can get the probabilities from the two events table (Table 3).

This can be done by utilizing the "double period", made up of the two single periods. The Rain Counts, Table 4, is:

	1st Period	2nd Period	Double Period
	Ra Rb	Ra Rc	Ra Rb Rc
Total Rains	(Ra+Rb)	(Ra+Rc)	Ra+Rb+Rc

Ra =	(Ra + Rb)	+	(Ra + Rc)	-	(Ra + Rb + Rc)
=	F1	+	F2	-	Fd
Rb =	(Ra + Rb)	-	Ra		
=	F1	-	Ra		
Rc =	(Ra + Rc)	-	Ra		
=	F2	-	Ra		

Symbols: F_1 is freq. first period. F_2 is freq. second period. F_d is freq. double period.

Table 4 shows that, if the double period frequency can be derived from the frequencies of the two periods, then Ra, Rb, and Rc can be determined. The assumption necessary and the method of determining the double period frequencies for all combinations of single-period frequencies from 5% to 90% follow.

2. GETTING THE DOUBLE-PERIOD FREQUENCIES FROM ALL COMBINATIONS OF SINGLE-PERIOD FREQUENCIES

There are 2 steps:

First, get double-period frequencies when single-period frequencies are the same. This requires the assumption:

$$\frac{\text{rain freq. double prd}}{\text{rain freq. single prd}} = 3/2 = 1.50 = \text{the RATIO.}$$

These are graphed and tabled in Figure 1.

Second, get double-period frequencies from any combination of single-period frequencies. The procedure may be illustrated by an example:

Single Prd Freq	Single Prd Freq	Double Prd Freq
40%	40%	60%
30	40	55
20	40	50
10	40	45
0	40	40

using the assumption above by linear interpolation between 60% (for 40% and 40%) and the 40% (for 0% and 40%)

OBVIOUS

The Interpolation Graph is Graph 1. It covers all combinations of single-period frequencies from 5% to 90%.

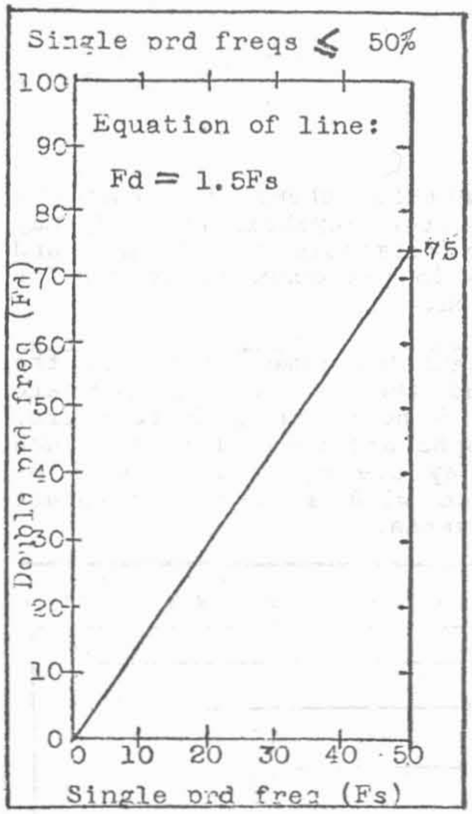


Table from above:

Fs	Fs	Fd
02	02	03
05	05	075
10	10	15
20	20	30
30	30	45
40	40	60
50	50	75

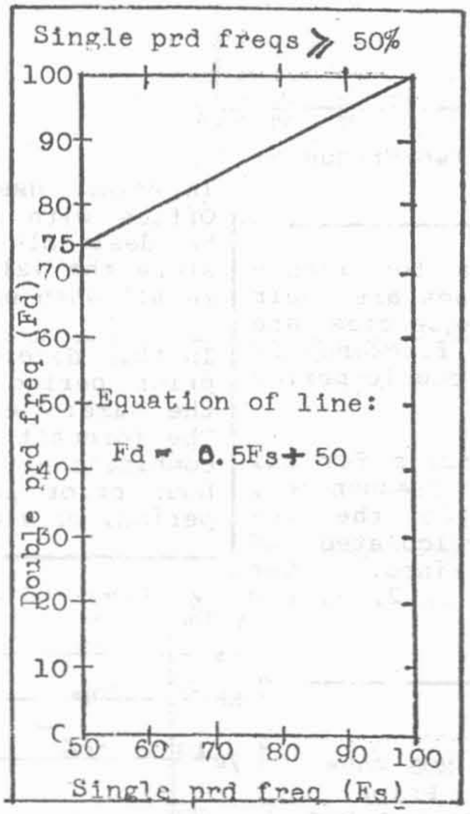
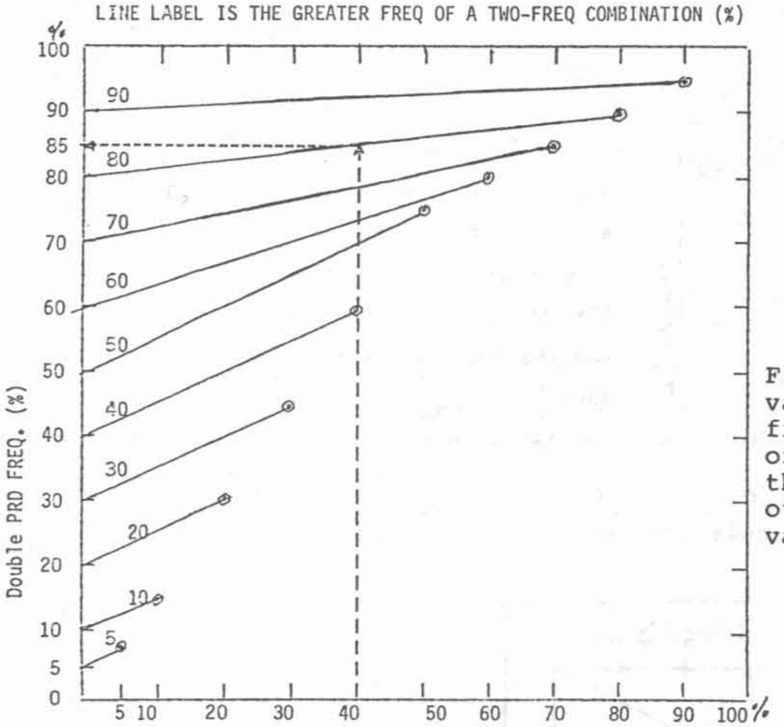


Table from above:

Fs	Fs	Fd
50	50	75
60	60	80
70	70	85
80	80	90
90	90	95

Symbols:
Fd is frequency of double period.
Fs is frequency of single period.

Figure 1. Double-period frequencies of two single periods, each with same frequency. In left-hand plot the double-period frequency is assumed to be 1.50 times the single-period frequency up to a limit of 75%. In right-hand plot the double-period frequency varies linearly from that 75% point to its 100% limit.



The Lesser Frequency of a Two-Frequency Combination (%)

Figure 2. Double-period frequencies from various combinations of single-period frequencies. One of the end-point values of the labelled lines occurs when one of the single-period frequencies is 0%; the other when the two are the same. Linear variation assumed.

Double-period frequency values for right-hand end points of labelled lines are their values when single-period frequencies are the same. For example; if one frequency is 40% and the other is 80%, double-period frequency is 85%.

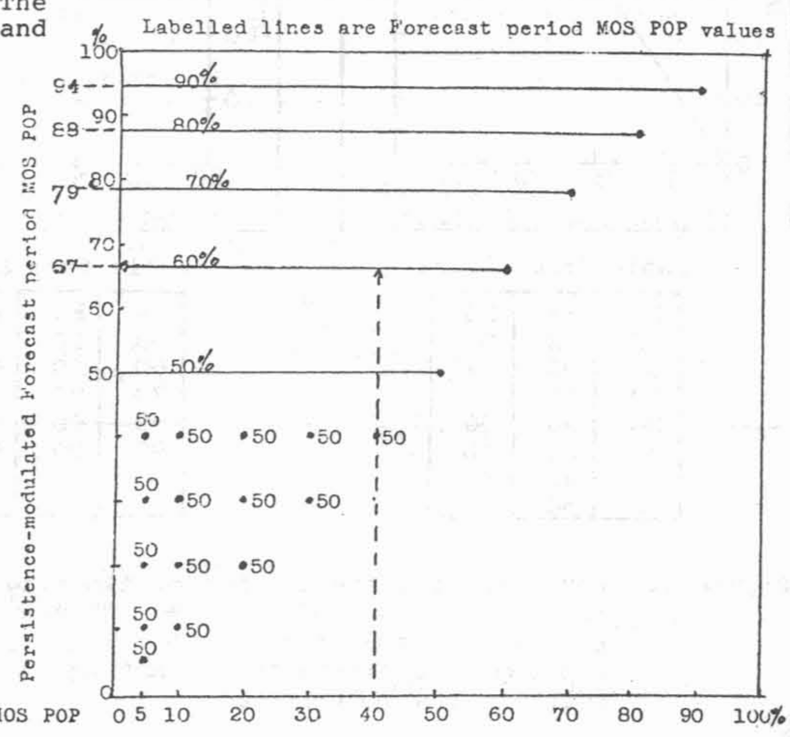
With the double-period frequencies for all combinations of single-period frequencies, the values of Ra, Rb, and Rc for the two-events table (Table 3) were calculated and the two probabilities determined. The results are graphed as Graphs 1, 2, 3, and 4, respectively.

In actual use of this scheme at a Forecast Office with computer capabilities, it may be desirable to eliminate the Graphs and store the values in the computer memory for recall when wanted.

In this development the time lengths of the prior period and the forecast period are the same: each 6 hours or each 12 hours. The forecast graphs are valid for each such combination. They are not valid for a 6-hour prior period with a 12-hour forecast period, or vice-versa.

Graph 1.

Modulated Forecast Period MOS PoPs When Rain in Prior Period; Prior Period MOS PoP≤Forecast Period MOS PoP (a RIPP Graph).

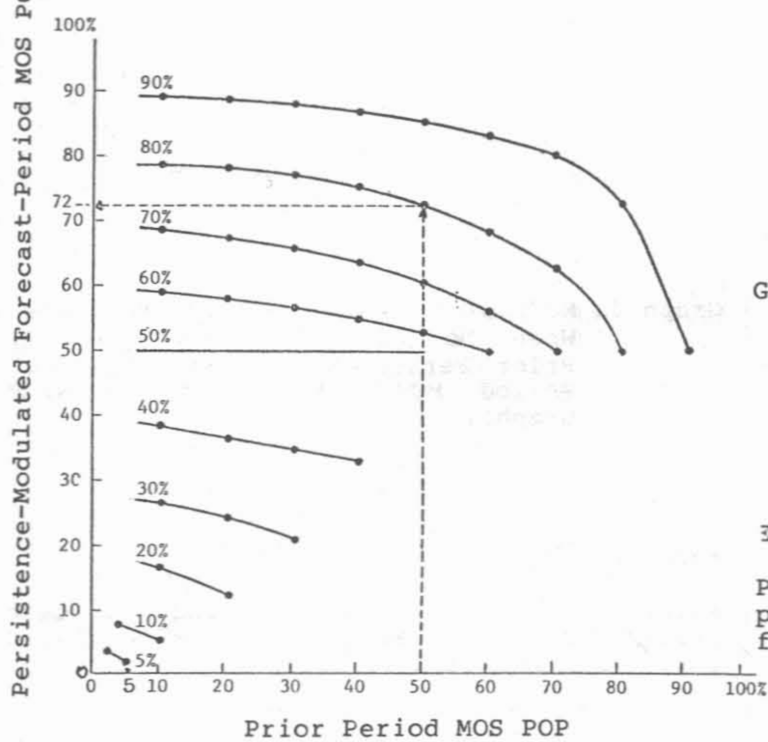


Examples:

A.
Prior period MOS POP 40% and forecast period MOS POP 60%, persistence-modulated forecast period MOS POP is 67%.

B.
Prior period MOS POP 10% and forecast period MOS POP 30%, persistence-modulated forecast period MOS POP is 50%.

Curve Values are Forecast-Period MOS POP Values.



Graph 2. Modulated Forecast Period MOS PoPs When No Rain in Prior Period; Prior Period MOS PoP ≤ Forecast Period MOS PoP (a NIPP Graph).

Example:

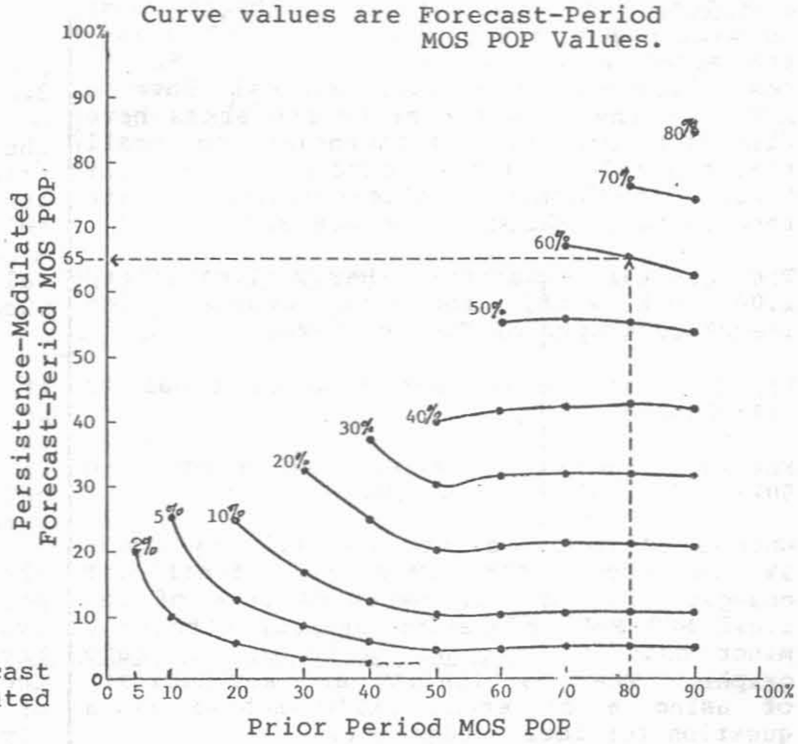
Prior period MOS POP 50% and forecast period MOS POP 80%, persistence-modulated forecast period MOS POP is 72%.

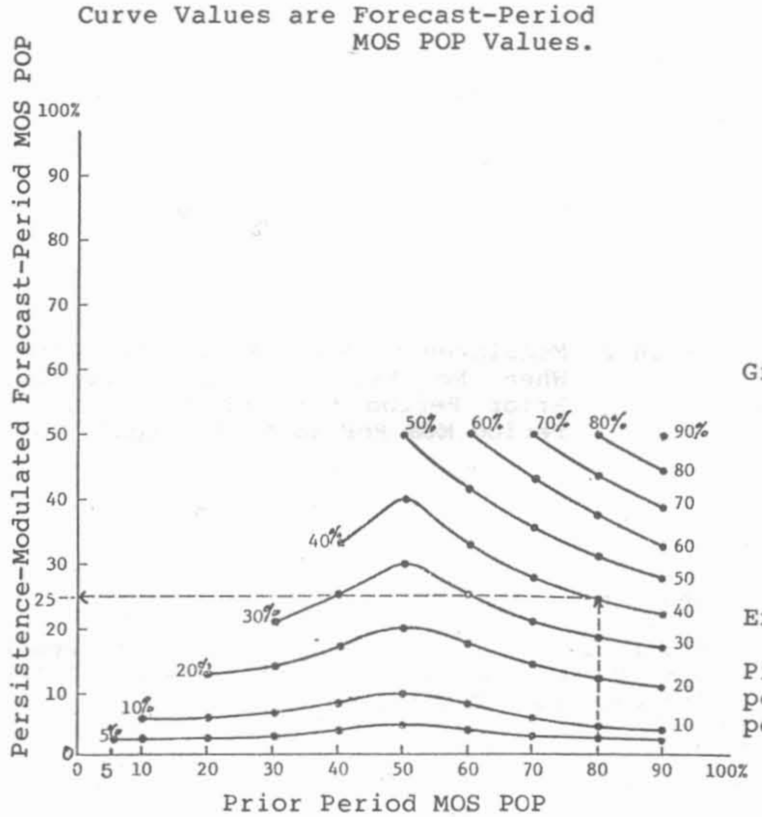
Graph 3.
Modulated Forecast Period MOS PoPs When Rain in Prior Period; Prior Period MOS PoPs > Forecast Period MOS PoP (a RIPP Graph).

Example:

Prior period MOS POP 80% and forecast period MOS POP 60%, persistence-modulated period MOS POP is 65%.

Curve values are Forecast-Period MOS POP Values.





Graph 4. Modulated Forecast Period MOS PoPs When No Rain in Prior Period; Prior Period MOS PoP ≥ Forecast Period MOS PoP Values (a NIPP Graph).

Example:

Prior period MOS POP 80% and forecast period MOS POP 40%, persistence-modulated period MOS POP is 25%.

The function that has determined the results herein is the RATIO (R) used to get the double-period frequencies from the two graphs of Figure 1.

It is not to be expected that this 1.50 RATIO would be universal over the vast United States with its wide variations of seasonal and diurnal climates. For examples, the rainy Pacific Northwest Coast in winter has a RATIO in the 1.40 class; the areas with diurnal showers of Summer (especially in the Gulf States) have a RATIO in the 1.60 class; desert areas have climatological rain frequencies so small that the rules for the rounding of decimals before publishing climatological data renders their RATIO values suspect.

The general equations (RATIO limits are 1.00 and 2.00) for the double-period frequency graphs of Figure 1 are:

For Fs frequencies less than or equal to 50%: $Fd=RFs$

For Fs frequencies greater than or equal to 50%: $Fd=(2.00-R)Fs+(R-1.00)$

When a RATIO different from 1.50 by about 5% is used there may be significant changes, but only in parts of some of the final MOS PoP modulation graphs, with only minor changes in other parts of the same graphs. The practicality and advisability of using a different RATIO scheme is a question for local judgement.

Outside the rainy Pacific Northwest Coast in winter and the dry desert areas, stations may find the use of this RATIO 1.50 scheme in winter, spring and fall seasons and the use of a 1.60 scheme in summer would be a reasonable plan for quantification of their persistence regime (assumption A).

3. REMARKS

The persistence probabilities produced by this scheme are not forecasts in the usual sense. They should be considered "MODULATED" MOS PoPs, and this scheme is a strategy - a disciplined strategy that tells the forecaster when, how, and how much to modulate MOS PoP.

In cases where there has been no rain in the prior period hours up to the forecaster position time (Figure 1), the occurrence of rain in the 2 hours remaining until the beginning of the Forecast period will change the situation to RIPP. A 2-hour forecast is necessary.

The probability to be used for the prior period is specified as "its latest available MOS PoP." Such a MOS PoP must have been received before the beginning of the prior period and that might be 12 hours or more before the forecaster position time.

The number of RIPP designations is a function of the length of the prior period, being smaller for a short period than a long one. The number of NIPP designations is complementary to these. Setting the lengths of the prior period and the forecast period the same was deemed a reasonable balance. In the long run the frequency of the number of RIPP forecasts will equal the climatic frequency of rain (C). And the frequency of the number of NIPP forecasts will be (1-C).

Assumption A has been checked for six stations using climatological data from ESSA Technical Report WB 5 (3). The average yearly values of the 12-hour to 6-hour and the 24-hour to 12-hour Ratios are:

CITY	12 to 6 hours	24 to 12 hours
New York City	1.44	1.44
Salt Lake City	1.50	1.51
Detroit	1.51	1.52
Minneapolis	1.51	1.52
Chicago	1.53	1.49
Kansas City	1.56	1.51
Average	1.51	1.51

In TDL 31 (2) it is shown that persistence-modulated climatological probability forecasts produce better skill scores than straight climatological forecasts will. In analogous fashion the persistence-modulated MOS POP forecasts will produce better skill scores than the straight MOS POP forecasts will.

Throughout this paper the MOS POP for the first forecast period was used as the target probability to be modulated by persistence. The results are not so restricted, and the POP modulation graphs can be used with other probabilistic forecasts. One example of such is a POP forecast generated locally. For instance, a local forecaster may have independently arrived at a probability of rain that is different than MOS POP. If such a local POP is arrived at solely from synoptic and prognostic charts (NO Persistence factor included) the modulation graphs can then be applied to that local POP. The local forecaster must be careful that he does not use any persistence factor more than once. This scheme has not been comprehensively tested because that would require many years of data. However, a comparison can be made with the results in TDL 31 (2) wherein 15 years of real data was used. The comparison is limited to the range of climatological probabilities used in TDL 31. For six stations a significantly large percentage of RIPP values were within seven percentage points of WET values and practically all NIPP values were within two percentage points of DRY values. These are considered well within tolerable meteorological limits.

References and Footnotes

1. John E. Hovde received his B.S. degree in Engineering from the University of Minnesota in 1932 and his M.S. in Meteorology from NYU in 1940. He served in the U.S. Weather Bureau and National Weather Service for 39 years, the last 32 of them in various forecasting assignments. He retired in 1970.

2. Jorgensen, D.L., and W.H. Klein, 1970: Persistence of precipitation at 108 cities in the conterminous United States. ESSA Technical Memorandum WBTM-TDL 31, May.

3. Jorgensen, D.L., 1967: Climatological probabilities of precipitation for the conterminous United States. ESSA Technical REport WB-5, December.