U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
SYSTEMS DEVELOPMENT OFFICE
TECHNIQUES DEVELOPMENT LABORATORY

TDL OFFICE NOTE 78-10

# EXPERIMENTAL RATE OF PAN EVAPORATION FORECASTS--PHASE II

John S. Jensenius, Jr. and Gary M. Carter

June 1978

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## 1. INTRODUCTION

During the summer of 1977, the Techniques Development Laboratory (TDL) produced experimental objective forecasts of the rate of pan evaporation (RPE) for 24-h periods for 66 stations in the National Weather Service (NWS) Western Region (Carter and Jensenius, 1977). During this period, the forecasts were subjectively evaluated by NWS forecasters who routinely made forecasts related to the RPE. Their major criticism of the objective RPE guidance was that it was too heavily influenced by climatology, and therefore, seldom predicted rapid changes in the RPE or large deviations from climatological normals.

In an attempt to reduce these problems we have developed a new RPE forecast system. Guidance for 30 stations in the Western Region (see Figure 1) is being transmitted via teletypewriter during June through September of 1978. These forecasts should be of interest to those NWS forecasters who are involved with agricultural forecasts of parameters related to pan evaporation, particularly in areas of critical water shortages.

## 2. DEVELOPMENTAL METHOD

All the RPE prediction equations were developed with use of the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). This technique consists of determining statistical relationships between local weather observations (predictands) and the output of numerical models (predictors). A forward stepwise selection procedure was used to derive multiple linear regression equations for predicting the RPE. The RPE equations were limited to 10 predictors with each predictor entering an equation being required to reduce the variance by at least one tenth of one percent.

Figure 2 shows the periods covered by the evaporation guidance and the sources of predictors for both the 0000 GMT and 1200 GMT forecast cycles. For 0000 GMT, forecast fields from the six-layer Primitive Equation (PE) and Trajectory (TRAJ) models were screened. In contrast, we used Limited-area Fine Mesh (LFM) and six-layer PE model output to develop the prediction equations for the 1200 GMT cycle. Some forecast fields were space smoothed over five or nine model grid points in order to reduce the amount of small scale noise inherent in numerical output. The forecast fields were then interpolated to the locations of each of the stations.

The variables available to the regression program as potential predictors of the RPE are similar to those used last year (Carter and Jensenius, 1977). They included 1000-, 850-, 700- and 500-mb temperatures; 850-, 700- and 500-mb heights; boundary layer, 850- and 500-mb winds; boundary layer, 850-, 700- and 500-mb vertical velocities; surface, 850-, 700- and 500-mb dewpoints and dewpoint depressions; several low and middle level mean relative humidities; several stability indicies; boundary layer wind and moisture divergence; boundary layer vorticity; surface pressure; boundary layer potential temperature; precipitation amount; precipitable water; and several climatological predictors.

In an attempt to determine the best way to lessen the dominating role of climatology in the RPE predictions, we developed three sets of equations, each differing only in the type and number of climatological predictors available to the screening program. Each set consisted of equations for each of the 66 stations we used for last year's operational forecasts. Four years (1973-76) of data were used to develop these equations.

The first set of equations (Harmonics) contained trigonometric functions of the day of the year and of twice the day of the year, in addition to MOS predictors from the PE, TRAJ, and LFM models. In contrast, the only climatological predictor available to the second set of equations (Daily Insolation) was the daily insolation at the top of the atmosphere. The third set (No Climatological Predictors) contained only MOS predictors. In addition to the standard forecasts from each set of equations, we also tested forecasts made with use of an "inflation" procedure similar to those described by Klein et al. (1959) and Russo et al. (1964). All six sets of forecasts were tested on one summer (June-September, 1977) of independent data. We compared mean absolute errors and time-differenced S1 scores (Dallavalle and Grayson, 1978) for each set of test equations. The time-differenced S1 scores were used to measure each equation set's ability to forecast day-to-day trends in pan evaporation.

Tables 1 and 2 show the mean absolute errors and the time-differenced S1 scores for each set of test equations. Also included are mean absolute errors and S1 scores for persistence. For Table 2, please note that forecasts of persistence always have time-differenced S1 scores of unity. The overall verification results indicate that the uninflated forecasts from the set of equations comprised of daily insolation and various MOS predictors was best for predicting pan evaporation. This set, however, was only slightly better than several of the other sets of equations, and also slightly better than forecasts of persistence.

In a further attempt to improve the forecasts, we rederived the 'Daily Insolation' RPE equation set and also included past evaporation observations as predictors. The test verification results for these equations are also given in Tables 1 and 2. Generally, the use of past evaporation observations in the RPE equations did not significantly improve the forecasts.

On the basis of these tests, we decided to limit the climatological predictors to only daily insolation, and also decided not to inflate the forecasts. In addition, we limited this year's guidance to the best 30 of the original 66 stations. These 30 stations were selected on the basis of both developmental and test sample results. For the 4-year developmental sample, both the reductions of variance and standard errors of estimate (Table 3) were considered. For the independent sample, we compared improvements over persistence in both mean absolute errors (Table 4) and time-differenced S1 scores (Table 5). Again, for Table 5, please note that forecasts of persistence always have S1 scores of unity.

We redeveloped the RPE equations for the 30 stations using all 5 years (1973-77) of data with daily insolation being the only climatological predictor allowed to enter the equations. The overall mean reduction of variance for all stations and projections combined was 49%. Standard errors of estimate for all stations and projections averaged .076 inches. Table 6 gives reductions of variance and standard errors of estimate for each of the 30 stations.

## 3. EQUATION CHARACTERISTICS

Almost all of the RPE equations contain the maximum limit of 10 predictors. The daily insolation was overwhelmingly the best singular predictor of the RPE. It was selected first by the regression program more than 75% of the time and first or second more than 95% of the time. The daily insolation also accounted for a large percentage of the total variance explained by the regression equations. Other important predictors of the RPE were low and middle level mean relative humidities; 850- and 700-mb temperatures; and boundary layer, 850- and 700-mb winds.

A sample RPE equation for the 0000 GMT 36-60 h projection at Brannan Island, California is given in Table 7. The equation reduced the total variance by 56% and had a standard error of .07 inches. The first predictor entering this equation was the daily insolation which explained 30% of the variance. It was followed by the 36-h PE mean relative humidity, the 36-h PE 700-mb temperature, and the 60-h PE boundary layer V component of the wind which explained an additional 14%, 4%, and 3% of the variance, respectively. The remaining predictors in the equation each contributed less than 2% to the explained variance.

## 4. MESSAGES AND SCHEDULES

RPE forecasts are transmitted to the Western Region twice daily via RAWARC in three teletype bulletins (FXUS40/41/42). Sample FXUS40, FXUS41 and FXUS42 teletype bulletins are shown in Figure 3. Forecast values in these messages are in hundredths of an inch.

## 5. OPERATIONAL CONSIDERATIONS

All of the RPE equations were developed on output from the six-layer PE model, six-layer PE based TRAJ model, and the LFM model. Operationally, the equations are being applied to the seven-layer PE model, seven-layer PE based TRAJ model, and the LFM-II model. As a result, the statistical prediction equations may not fully account for characteristic differences between old and new versions of the various numerical models.

In addition, forecasters using the RPE guidance should be aware that the forecast values are rates of pan evaporation, not evapotranspiration. Also, because daily insolation is such an important predictor in most of the RPE equations, extreme fluctuations from climatological normals may not often be predicted.

## 6. ACKNOWLEDGMENTS

We are very grateful to Rich Wagoner of the Western Region SSD for supervising and coordinating several key aspects of this project. Further thanks are extended to Fred Marshall of TDL for his computer programming support.

## 7. REFERENCES

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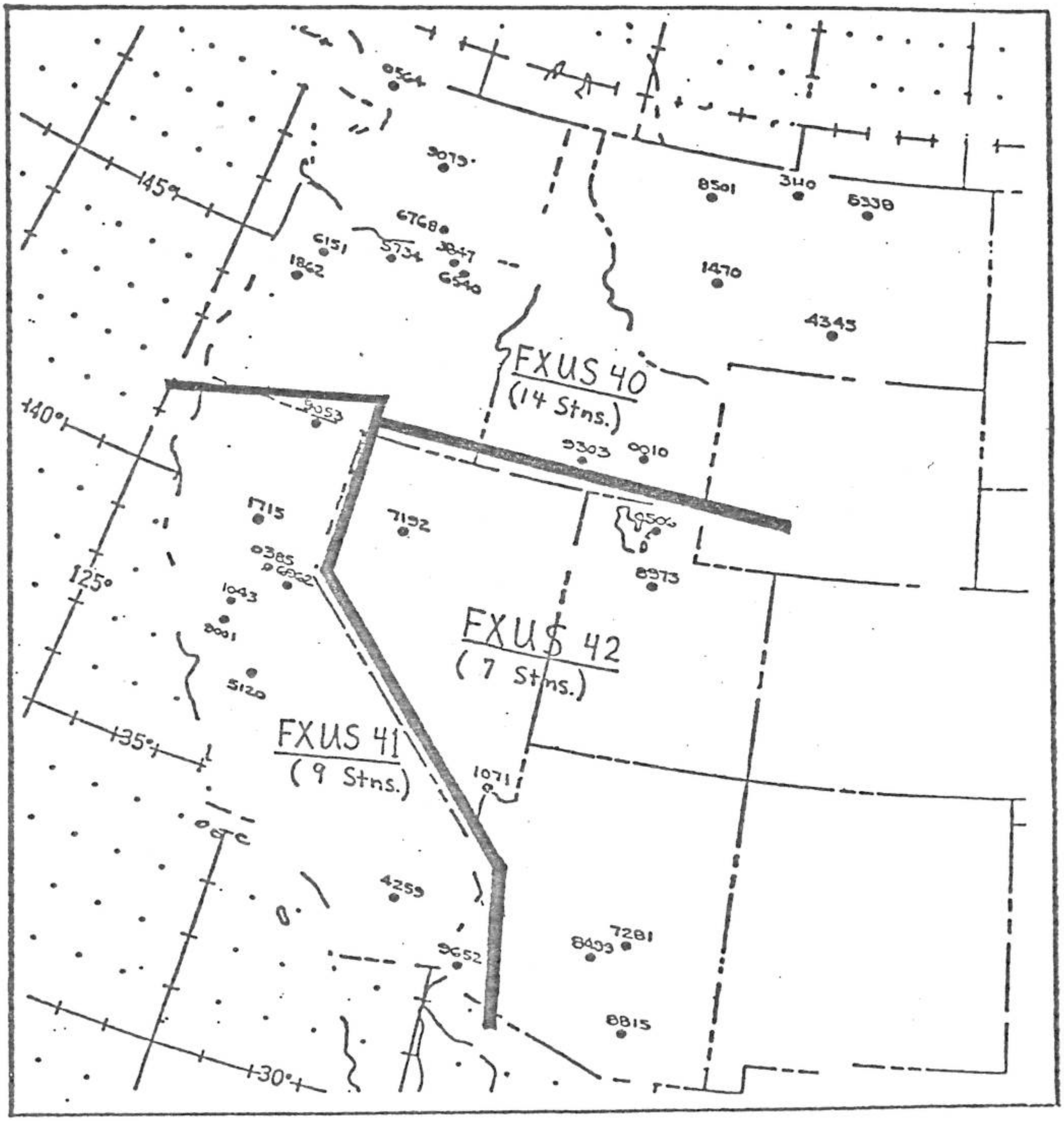


Figure 1. The 30 stations for which rate of pan evaporation guidance is available during the summer of 1978. Also shown are the bulletins in which these forecasts appear as well as the individual station identification numbers.

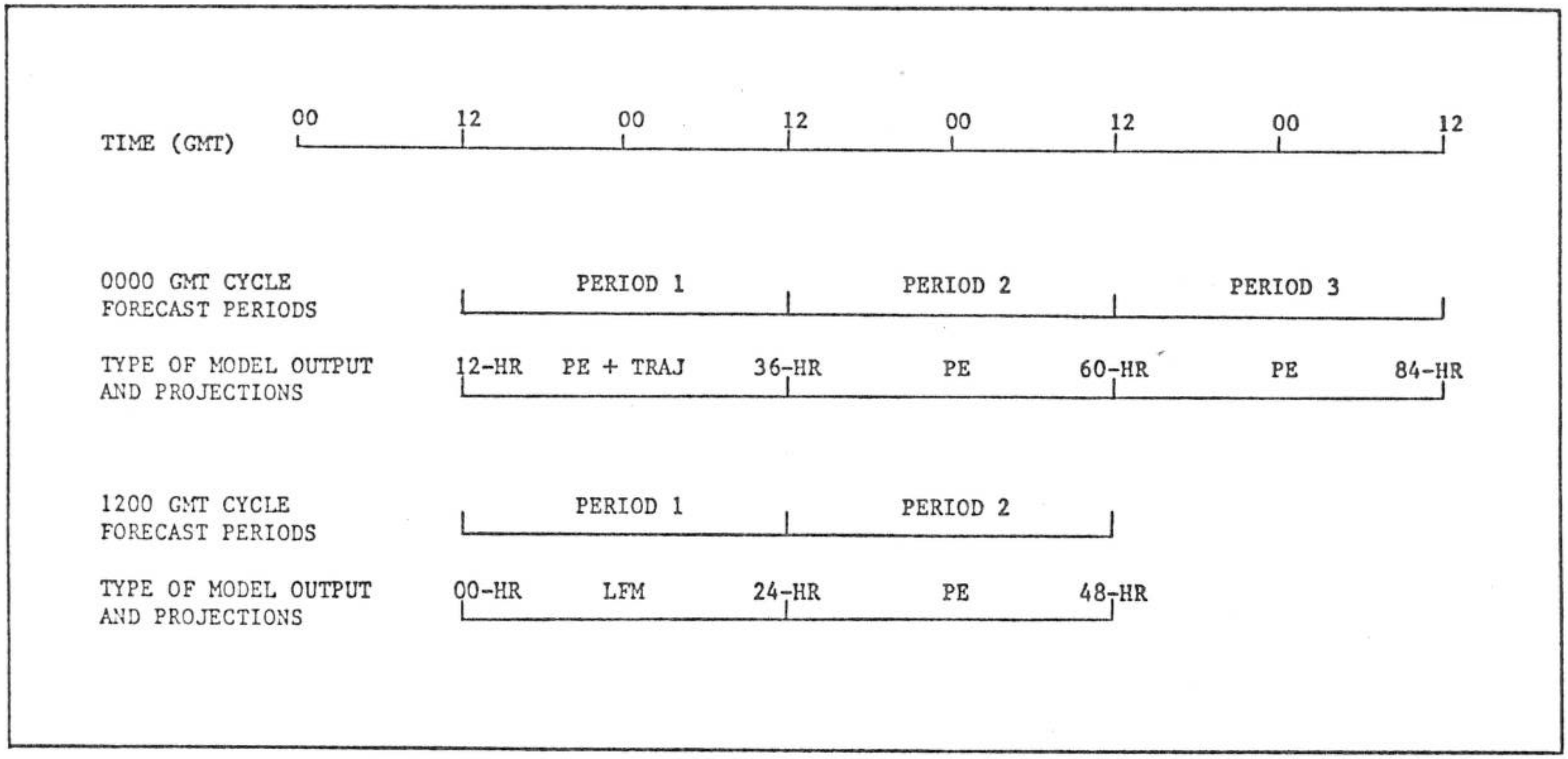


Figure 2. The periods covered by the evaporation forecasts and the source of model predictors for both the 0000 GMT and 1200 GMT forecast cycles.

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NNNN↓↓A
ZCZC WBC796
FXUS40 KWBC 080000
 FOLLOWING FOR INTERNAL NWS USE--NOT FOR PUBLIC DISSEMINATION
 EXPERIMENTAL RATE OF PAN EVAPORATION FCSTS   6/ 8/78
 PERIOD- 1200GMT TO 1200GMT
      09/12 10/12 11/12        09/12 10/12 11/12
0010   32    32    32    9303   33    29    26

1470   25    22    22    3110   25    20    20

4345   31    29    27    5338   26    24    22

8501   27    22    22    1862   19    14    19

3847   36    36    32    5734   35    32    32

6151   18    14    11    0564   16    15    15

6768   32    33    27    9079   27    29    24


NNNN↓↓A
ZCZC WBC797
FXUS41 KWBC 080000
 FOLLOWING FOR INTERNAL NWS USE--NOT FOR PUBLIC DISSEMINATION
 EXPERIMENTAL RATE OF PAN EVAPORATION FCSTS   6/ 8/78
 PERIOD- 1200GMT TO 1200GMT
      09/12 10/12 11/12        09/12 10/12 11/12
0385   38    36    35    1043   42    42    39

1715   44    40    37    4259   58    57    52

5120   66    67    58    6962   26    26    24

9001   56    59    50    9053   31    27    28

9652   50    49    46


NNNN↓↓A
ZCZC WBC798
FXUS42 KWBC 080000
 FOLLOWING FOR INTERNAL NWS USE--NOT FOR PUBLIC DISSEMINATION
 EXPERIMENTAL RATE OF PAN EVAPORATION FCSTS   6/ 8/78
 PERIOD- 1200GMT TO 1200GMT
      09/12 10/12 11/12        09/12 10/12 11/12
7281   49    52    52    8499   41    40    40

8815   57    59    53    1071   48    57    48

7192   31    36    26    0506   34    34    33

8973   29    34    31
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Figure 3. Sample FXUS40, FXUS41 and FXUS42 teletype bulletins.

Table 1. Overall average mean absolute errors for each set of MOS rate of evaporation prediction equations when tested on one summer (June-September, 1977) of independent data. The average mean absolute errors for forecasts of persistence are also included for purposes of comparison.

| Equation Set | 0000 GMT Period 1 12 - 36 h | 0000 GMT Period 2 36 - 60 h | 0000 GMT Period 3 60 - 84 h | 1200 GMT Period 1 12 - 36 h | 1200 GMT Period 2 36 - 60 h |
|---|---|---|---|---|---|
| Harmonics | .06 | .07 | .07 | .06 | .07 |
| Daily Insolation | .06 | .07 | .07 | .06 | .07 |
| No Clim. Pred. | .07 | .08 | .08 | .07 | .08 |
| Harmonics (Inflated) | .07 | .07 | .08 | .07 | .07 |
| Daily Insolation (Inflated) | .07 | .07 | .08 | .07 | .07 |
| No Clim. Pred. (Inflated) | .08 | .09 | .10 | .09 | .07 |
| Persistence | .08 | .08 | .09 | .08 | .08 |
| Daily Insolation (with evaporation observations) | .06 | .07 | .07 | .06 | .06 |

Table 2. Overall average time-differenced S1 scores for each set of evaporation equations when tested on one summer (June-September, 1977) of independent data.

| Equation Set | 0000 GMT Period 1 to Period 2 | 0000 GMT Period 2 to Period 3 | 0000 GMT Period 1 to Period 3 | 1200 GMT Period 1 to Period 2 |
|---|---|---|---|---|
| Harmonics | .97 | .98 | .93 | .94 |
| Daily Insolation | .96 | .98 | .93 | .94 |
| No Clim. Pred. | .97 | .98 | .95 | .95 |
| Harmonics (Inflated) | .96 | .97 | .91 | .93 |
| Daily Insolation (Inflated) | .96 | .97 | .91 | .93 |
| No Clim. (Inflated) | .96 | .98 | .94 | .95 |
| Persistence | 1.00 | 1.00 | 1.00 | 1.00 |
| Daily Insolation (with evaporation observations) | .97 | .98 | .93 | .94 |

Table 3. Developmental (4-year sample) reductions of variance and standard errors of estimate for evaporation equations for each of the best 30 stations.

| Stn. No. | Station Name | 0000 GMT Period 1 12 - 36 hr RDVR | 0000 GMT Period 1 12 - 36 hr STD ERR | 0000 GMT Period 2 36 - 60 hr RDVR | 0000 GMT Period 2 36 - 60 hr STD ERR | 0000 GMT Period 3 60 - 84 hr RDVR | 0000 GMT Period 3 60 - 84 hr STD ERR | 1200 GMT Period 1 00 - 24 hr RDVR | 1200 GMT Period 1 00 - 24 hr STD ERR | 1200 GMT Period 2 00 - 48 hr RDVR | 1200 GMT Period 2 00 - 48 hr STD ERR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5338 | Malta 7 E, MT | 0.545 | 0.061 | 0.472 | 0.064 | 0.476 | 0.064 | 0.602 | 0.057 | 0.479 | 0.063 |
| 3110 | Fort Assinniboine, MT | 0.390 | 0.081 | 0.407 | 0.081 | 0.357 | 0.086 | 0.501 | 0.077 | 0.399 | 0.081 |
| 8501 | Valier, MT | 0.409 | 0.070 | 0.390 | 0.071 | 0.306 | 0.075 | 0.544 | 0.061 | 0.417 | 0.070 |
| 1470 | Canyon Ferry, MT | 0.448 | 0.069 | 0.428 | 0.073 | 0.385 | 0.075 | 0.524 | 0.063 | 0.441 | 0.071 |
| 4345 | Huntley Exp Sta, MT | 0.414 | 0.076 | 0.428 | 0.077 | 0.380 | 0.080 | 0.431 | 0.079 | 0.419 | 0.077 |
| 0010 | Aberdeen Exp Sta, ID | 0.462 | 0.083 | 0.368 | 0.089 | 0.322 | 0.094 | 0.480 | 0.082 | 0.406 | 0.087 |
| 9303 | Twin Falls WSO, ID | 0.478 | 0.064 | 0.438 | 0.067 | 0.372 | 0.071 | 0.583 | 0.057 | 0.445 | 0.066 |
| 1662 | Corvallis State Col, OR | 0.556 | 0.063 | 0.451 | 0.070 | 0.382 | 0.075 | 0.597 | 0.060 | 0.482 | 0.067 |
| 6151 | No Willamette Exp Sta, OR | 0.559 | 0.066 | 0.452 | 0.074 | 0.378 | 0.079 | 0.612 | 0.063 | 0.499 | 0.070 |
| 5734 | Moro, OR | 0.607 | 0.071 | 0.546 | 0.077 | 0.495 | 0.082 | 0.680 | 0.067 | 0.607 | 0.072 |
| 3347 | Hermiston 2 S, OR | 0.530 | 0.067 | 0.485 | 0.070 | 0.472 | 0.071 | 0.630 | 0.061 | 0.503 | 0.069 |
| 6768 | Prosser 4 NE, WA | 0.452 | 0.069 | 0.426 | 0.071 | 0.445 | 0.070 | 0.536 | 0.065 | 0.469 | 0.069 |
| 9079 | Wenatchee Exp Sta, WA | 0.486 | 0.079 | 0.459 | 0.080 | 0.457 | 0.082 | 0.574 | 0.073 | 0.501 | 0.077 |
| 0564 | Bellingham 2 N, WA | 0.379 | 0.058 | 0.301 | 0.062 | 0.303 | 0.061 | 0.446 | 0.055 | 0.355 | 0.059 |
| 9053 | Tulelake, CA | 0.402 | 0.056 | 0.317 | 0.060 | 0.335 | 0.061 | 0.485 | 0.053 | 0.353 | 0.059 |
| 1715 | Chico Univ Farm, CA | 0.470 | 0.086 | 0.390 | 0.095 | 0.372 | 0.097 | 0.452 | 0.093 | 0.428 | 0.091 |
| 0335 | Auburn Dam Project, CA | 0.597 | 0.054 | 0.497 | 0.061 | 0.464 | 0.064 | 0.611 | 0.056 | 0.535 | 0.058 |
| 6962 | Placerville IRG, CA | 0.715 | 0.041 | 0.580 | 0.051 | 0.511 | 0.055 | 0.711 | 0.041 | 0.668 | 0.045 |
| 1043 | Brannan Island, CA | 0.605 | 0.065 | 0.558 | 0.069 | 0.509 | 0.074 | 0.671 | 0.060 | 0.594 | 0.066 |
| 9001 | Tracy Pumping Plant, CA | 0.528 | 0.099 | 0.506 | 0.102 | 0.433 | 0.111 | 0.609 | 0.093 | 0.502 | 0.103 |
| 5120 | Los Banos Det Resv, CA | 0.717 | 0.079 | 0.661 | 0.089 | 0.583 | 0.099 | 0.722 | 0.080 | 0.698 | 0.083 |
| 4259 | Indio US Date Garden, CA | 0.580 | 0.078 | 0.529 | 0.082 | 0.480 | 0.085 | 0.618 | 0.074 | 0.535 | 0.081 |
| 9652 | Yuma Citrus Sta, AZ | 0.535 | 0.066 | 0.576 | 0.062 | 0.569 | 0.068 | 0.569 | 0.064 | 0.523 | 0.067 |
| 0506 | Bear River Refuge, UT | 0.562 | 0.063 | 0.521 | 0.066 | 0.491 | 0.070 | 0.594 | 0.060 | 0.550 | 0.065 |
| 8973 | Utah Lake Lehl, UT | 0.339 | 0.083 | 0.260 | 0.086 | 0.224 | 0.090 | 0.413 | 0.077 | 0.321 | 0.084 |
| 7192 | Rye Patch Dam, NV | 0.380 | 0.080 | 0.347 | 0.085 | 0.372 | 0.082 | 0.452 | 0.076 | 0.344 | 0.083 |
| 1071 | Boulder City, NV | 0.540 | 0.092 | 0.540 | 0.094 | 0.429 | 0.104 | 0.551 | 0.092 | 0.550 | 0.090 |
| 7281 | Roosevelt 1 WNW, AZ | 0.454 | 0.095 | 0.418 | 0.099 | 0.327 | 0.108 | 0.465 | 0.098 | 0.391 | 0.102 |
| 8499 | Tempe UA Cit Exp Sta, AZ | 0.553 | 0.062 | 0.546 | 0.063 | 0.541 | 0.064 | 0.602 | 0.059 | 0.572 | 0.061 |
| 8815 | Tucson U of A, AZ | 0.563 | 0.091 | 0.454 | 0.102 | 0.406 | 0.107 | 0.583 | 0.086 | 0.503 | 0.097 |

Table 4. Mean absolute errors for MOS evaporation forecasts and for forecasts of persistence for each of the best 30 stations when tested on one summer (June-September, 1977) of independent data.

| Stn. No. | Station Names | 0000 GMT Period 1 12 - 36 hr | | 0000 GMT Period 2 36 - 60 hr | | 0000 GMT Period 3 60 - 84 hr | | 1200 GMT Period 1 00 - 24 hr | | 1200 GMT Period 2 24 - 48 hr | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MOS | Pers. | MOS | Pers. | MOS | Pers. | MOS | Pers. | MOS | Pers. |
| 5338 | Malta 7 E, MT | 0.05 | 0.07 | 0.05 | 0.07 | 0.06 | 0.07 | 0.04 | 0.07 | 0.05 | 0.08 |
| 3110 | Fort Assinniboine, MT | 0.05 | 0.08 | 0.06 | 0.09 | 0.06 | 0.09 | 0.05 | 0.08 | 0.06 | 0.09 |
| 8501 | Valier, MT | 0.06 | 0.08 | 0.07 | 0.10 | 0.08 | 0.10 | 0.06 | 0.08 | 0.07 | 0.11 |
| 1470 | Canyon Ferry, MT | 0.06 | 0.08 | 0.06 | 0.08 | 0.06 | 0.09 | 0.06 | 0.08 | 0.06 | 0.08 |
| 4345 | Huntley Exp Sta, MT | 0.07 | 0.10 | 0.07 | 0.10 | 0.07 | 0.10 | 0.07 | 0.10 | 0.07 | 0.10 |
| 0010 | Aberdeen Exp Sta, ID | 0.06 | 0.09 | 0.06 | 0.10 | 0.08 | 0.09 | 0.06 | 0.09 | 0.06 | 0.10 |
| 9303 | Twin Falls WSO, ID | 0.05 | 0.07 | 0.06 | 0.08 | 0.06 | 0.08 | 0.05 | 0.07 | 0.05 | 0.09 |
| 1862 | Corvallis State Col, OR | 0.05 | 0.06 | 0.06 | 0.08 | 0.07 | 0.09 | 0.05 | 0.06 | 0.06 | 0.08 |
| 6151 | No Williamette Exp Sta, OR | 0.08 | 0.10 | 0.09 | 0.10 | 0.09 | 0.11 | 0.08 | 0.10 | 0.08 | 0.10 |
| 5734 | Moro, OR | 0.07 | 0.09 | 0.07 | 0.10 | 0.08 | 0.11 | 0.06 | 0.08 | 0.07 | 0.10 |
| 3847 | Hermiston 2 S, OR | 0.07 | 0.09 | 0.07 | 0.11 | 0.08 | 0.11 | 0.07 | 0.09 | 0.07 | 0.11 |
| 6768 | Prosser 4 NE, WA | 0.06 | 0.04 | 0.06 | 0.05 | 0.06 | 0.09 | 0.06 | 0.07 | 0.06 | 0.08 |
| 9079 | Wenatchee Exp Sta, WA | 0.06 | 0.07 | 0.06 | 0.08 | 0.06 | 0.09 | 0.05 | 0.07 | 0.06 | 0.08 |
| 0564 | Bellingham 2 N, WA | 0.04 | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.04 | 0.05 |
| 9053 | Tulelake, CA | 0.07 | 0.09 | 0.08 | 0.12 | 0.08 | 0.09 | 0.07 | 0.10 | 0.07 | 0.10 |
| 1715 | Chico Univ Farm, CA | 0.07 | 0.08 | 0.07 | 0.10 | 0.07 | 0.11 | 0.07 | 0.08 | 0.07 | 0.10 |
| 0395 | Auburn Dam Project, CA | 0.05 | 0.07 | 0.05 | 0.07 | 0.06 | 0.08 | 0.05 | 0.07 | 0.05 | 0.08 |
| 6962 | Placerville IRG, CA | 0.06 | 0.06 | 0.06 | 0.09 | 0.06 | 0.10 | 0.05 | 0.06 | 0.05 | 0.09 |
| 1043 | Brannan Island, CA | 0.05 | 0.07 | 0.05 | 0.07 | 0.06 | 0.10 | 0.04 | 0.07 | 0.06 | 0.07 |
| 9001 | Tracy Pumping Plant, CA | 0.08 | 0.10 | 0.09 | 0.12 | 0.09 | 0.12 | 0.07 | 0.09 | 0.09 | 0.12 |
| 5120 | Los Banos Det Resv, CA | 0.09 | 0.09 | 0.09 | 0.12 | 0.09 | 0.13 | 0.09 | 0.09 | 0.09 | 0.12 |
| 4259 | Indio US Date Garden, CA | 0.06 | 0.06 | 0.07 | 0.08 | 0.07 | 0.09 | 0.06 | 0.06 | 0.06 | 0.08 |
| 9652 | Yuma Citrus Sta, AZ | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 | 0.08 | 0.05 | 0.06 | 0.05 | 0.07 |
| 0506 | Bear River Refuge, UT | 0.05 | 0.07 | 0.05 | 0.07 | 0.05 | 0.07 | 0.05 | 0.07 | 0.05 | 0.07 |
| 8973 | Utah Lake Lehl, UT | 0.08 | 0.12 | 0.08 | 0.11 | 0.08 | 0.10 | 0.07 | 0.11 | 0.08 | 0.11 |
| 7192 | Rye Patch Dam, NV | 0.07 | 0.09 | 0.06 | 0.09 | 0.06 | 0.09 | 0.05 | 0.06 | 0.07 | 0.10 |
| 1071 | Boulder City, NV | 0.08 | 0.12 | 0.08 | 0.13 | 0.09 | 0.12 | 0.08 | 0.12 | 0.08 | 0.13 |
| 7281 | Roosevelt 1 WNW, AZ | 0.08 | 0.10 | 0.08 | 0.10 | 0.08 | 0.11 | 0.08 | 0.10 | 0.08 | 0.10 |
| 8499 | Tempa UA Cit Exp Sta, AZ | 0.05 | 0.06 | 0.05 | 0.07 | 0.05 | 0.07 | 0.05 | 0.06 | 0.06 | 0.07 |
| 8815 | Tucson U of A, AZ | 0.07 | 0.09 | 0.08 | 0.10 | 0.08 | 0.11 | 0.07 | 0.09 | 0.08 | 0.11 |

Table 5. Time-differenced S1 scores for MOS evaporation forecasts for each of the best 30 stations when tested on one summer (June-September, 1977) of independent data.

| Stn. No. | Station Name | 0000 GMT Period 1 to Period 2 | 0000 GMT Period 2 to Period 3 | 0000 GMT Period 1 to Period 3 | 1200 GMT Period 1 to Period 2 |
|---|---|---|---|---|---|
| 5338 | Malta 7 E, MT | 0.89 | 0.94 | 0.87 | 0.86 |
| 3110 | Fort Assinniboine, MT | 0.90 | 0.99 | 0.87 | 0.88 |
| 8501 | Valier, MT | 0.89 | 0.96 | 0.89 | 0.90 |
| 1470 | Canyon Ferry, MT | 0.97 | 0.91 | 0.90 | 0.92 |
| 4345 | Huntley Exp Sta, MT | 0.97 | 0.97 | 0.93 | 0.94 |
| 0010 | Aberdeen Exp Sta, ID | 0.89 | 0.96 | 0.91 | 0.84 |
| 9303 | Twin Falls WSO, ID | 0.91 | 0.96 | 0.94 | 0.88 |
| 1862 | Corvallis State Col, OR | 0.91 | 0.93 | 0.92 | 0.84 |
| 6151 | No Williamette Exp Sta, OR | 0.98 | 0.96 | 0.94 | 0.93 |
| 5734 | Moro, OR | 0.93 | 0.94 | 0.88 | 0.89 |
| 3847 | Hermiston 2 S, OR | 0.93 | 0.97 | 0.87 | 0.88 |
| 6768 | Prosser 4 NE, WA | 0.94 | 1.02 | 0.99 | 0.88 |
| 9079 | Wenatchee Exp Sta, WA | 0.97 | 0.97 | 0.92 | 0.89 |
| 0564 | Bellingham 2 N, WA | 0.93 | 0.99 | 0.91 | 0.89 |
| 9053 | Tulelake, CA | 0.97 | 0.95 | 0.94 | 0.94 |
| 1715 | Chico Univ Farm, CA | 0.94 | 1.00 | 0.92 | 0.95 |
| 0385 | Auburn Dam Project, CA | 0.93 | 0.98 | 0.92 | 0.89 |
| 6962 | Placerville IRG, CA | 0.90 | 1.06 | 0.92 | 0.87 |
| 1043 | Brannan Island, CA | 0.95 | 0.98 | 0.80 | 0.96 |
| 9001 | Tracy Pumping Plant, CA | 0.93 | 0.96 | 0.94 | 0.94 |
| 5120 | Los Banos Det Resv, CA | 0.89 | 0.96 | 0.87 | 0.93 |
| 4259 | Indio US Date Garden, CA | 0.93 | 0.94 | 0.85 | 0.91 |
| 9652 | Yuma Citrus Sta, AZ | 1.00 | 0.96 | 0.98 | 0.99 |
| 0506 | Bear River Refuge, UT | 0.97 | 0.98 | 0.95 | 0.95 |
| 8973 | Utah Lake Lehl, UT | 1.01 | 0.95 | 0.97 | 0.96 |
| 7192 | Rye Patch Dam, NV | 0.95 | 0.94 | 0.97 | 0.94 |
| 1071 | Boulder City, NV | 0.94 | 0.95 | 0.94 | 0.99 |
| 7281 | Roosevelt 1 WNW, AZ | 0.94 | 0.96 | 0.90 | 0.96 |
| 8499 | Tempe UA Cit Exp Sta, AZ | 0.95 | 0.94 | 0.93 | 0.96 |
| 8815 | Tucson U of A, AZ | 0.97 | 0.98 | 0.93 | 0.95 |

Table 6. Developmental (5-year sample) reductions of variance and standard errors of estimate for evaporation equations for each of the best 30 stations.

| Stn. No. | Station Name | 0000 GMT Period 1 12 - 36 hr | | 0000 GMT Period 2 36 - 60 hr | | 0000 GMT Period 3 60 - 84 hr | | 1200 GMT Period 1 00 - 24 hr | | 1200 GMT Period 2 24 - 48 hr | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RDVR | STD ERR | RDVR | STD ERR | RDVR | STD ERR | RDVR | STD ERR | RDVR | STD ERR |
| 5338 | Malta 7 E, MT | 0.570 | 0.060 | 0.473 | 0.065 | 0.462 | 0.065 | 0.615 | 0.057 | 0.501 | 0.063 |
| 3110 | Fort Assinniboine, MT | 0.435 | 0.077 | 0.416 | 0.079 | 0.379 | 0.083 | 0.517 | 0.074 | 0.417 | 0.079 |
| 8501 | Valier, MT | 0.421 | 0.072 | 0.389 | 0.074 | 0.315 | 0.079 | 0.534 | 0.065 | 0.392 | 0.075 |
| 1470 | Canyon Ferry, MT | 0.447 | 0.070 | 0.417 | 0.074 | 0.368 | 0.077 | 0.509 | 0.065 | 0.428 | 0.074 |
| 4345 | Huntley Exp Sta, MT | 0.415 | 0.078 | 0.416 | 0.079 | 0.368 | 0.082 | 0.430 | 0.080 | 0.409 | 0.079 |
| 0010 | Aberdeen Exp Sta, ID | 0.481 | 0.081 | 0.384 | 0.087 | 0.327 | 0.093 | 0.506 | 0.080 | 0.423 | 0.085 |
| 9303 | Twin Falls WSO, ID | 0.498 | 0.064 | 0.466 | 0.068 | 0.389 | 0.072 | 0.586 | 0.059 | 0.466 | 0.066 |
| 1862 | Corvallis State Col, OR | 0.569 | 0.064 | 0.466 | 0.073 | 0.388 | 0.077 | 0.612 | 0.060 | 0.500 | 0.068 |
| 6151 | No Williamette Exp Sta, OR | 0.480 | 0.076 | 0.395 | 0.083 | 0.342 | 0.087 | 0.525 | 0.074 | 0.431 | 0.080 |
| 5734 | Moro, OR | 0.641 | 0.075 | 0.607 | 0.079 | 0.554 | 0.085 | 0.703 | 0.070 | 0.647 | 0.074 |
| 3847 | Hermiston 2 S, OR | 0.549 | 0.071 | 0.509 | 0.074 | 0.488 | 0.076 | 0.620 | 0.067 | 0.531 | 0.072 |
| 6768 | Prosser 4 NE, WA | 0.517 | 0.069 | 0.501 | 0.070 | 0.496 | 0.071 | 0.575 | 0.066 | 0.505 | 0.070 |
| 9079 | Wenatchee Exp Sta, WA | 0.517 | 0.077 | 0.493 | 0.079 | 0.492 | 0.080 | 0.612 | 0.070 | 0.531 | 0.076 |
| 0564 | Bellingham 2 N, WA | 0.436 | 0.056 | 0.373 | 0.060 | 0.373 | 0.059 | 0.512 | 0.052 | 0.428 | 0.057 |
| 9053 | Tulelake, CA | 0.371 | 0.064 | 0.319 | 0.067 | 0.311 | 0.069 | 0.449 | 0.061 | 0.371 | 0.065 |
| 1715 | Chico Univ Farm, CA | 0.478 | 0.086 | 0.390 | 0.097 | 0.383 | 0.098 | 0.453 | 0.092 | 0.442 | 0.091 |
| 0385 | Auburn Dam Project, CA | 0.613 | 0.056 | 0.530 | 0.062 | 0.488 | 0.066 | 0.630 | 0.056 | 0.573 | 0.059 |
| 6962 | Placerville IRG, CA | 0.677 | 0.047 | 0.578 | 0.053 | 0.508 | 0.059 | 0.677 | 0.047 | 0.635 | 0.050 |
| 1043 | Brannan Island, CA | 0.622 | 0.064 | 0.564 | 0.069 | 0.514 | 0.074 | 0.678 | 0.060 | 0.598 | 0.066 |
| 9001 | Tracy Pumping Plant, CA | 0.532 | 0.100 | 0.507 | 0.104 | 0.443 | 0.111 | 0.610 | 0.093 | 0.507 | 0.104 |
| 5120 | Los Banos Det Resv, CA | 0.674 | 0.087 | 0.622 | 0.094 | 0.560 | 0.103 | 0.688 | 0.086 | 0.658 | 0.089 |
| 4259 | Indio US Date Garden, CA | 0.578 | 0.077 | 0.520 | 0.081 | 0.465 | 0.086 | 0.605 | 0.074 | 0.534 | 0.080 |
| 9652 | Yuma Citrus Sta, AZ | 0.528 | 0.067 | 0.443 | 0.101 | 0.530 | 0.068 | 0.595 | 0.063 | 0.547 | 0.067 |
| 0506 | Bear River Refuge, UT | 0.564 | 0.063 | 0.519 | 0.066 | 0.486 | 0.069 | 0.588 | 0.060 | 0.543 | 0.065 |
| 8973 | Utah Lake Lehi, UT | 0.310 | 0.087 | 0.253 | 0.090 | 0.235 | 0.092 | 0.391 | 0.081 | 0.304 | 0.088 |
| 7192 | Rye Patch Dam, NV | 0.407 | 0.080 | 0.378 | 0.084 | 0.394 | 0.082 | 0.475 | 0.076 | 0.367 | 0.084 |
| 1071 | Boulder City, NV | 0.524 | 0.092 | 0.490 | 0.097 | 0.412 | 0.104 | 0.522 | 0.093 | 0.497 | 0.095 |
| 7281 | Roosevelt 1 WNW, AZ | 0.465 | 0.093 | 0.433 | 0.096 | 0.360 | 0.104 | 0.472 | 0.096 | 0.405 | 0.100 |
| 8499 | Tempe UA Cit Exp Sta, AZ | 0.553 | 0.062 | 0.549 | 0.062 | 0.548 | 0.063 | 0.589 | 0.059 | 0.545 | 0.063 |
| 8815 | Tucson U of A, AZ | 0.541 | 0.091 | 0.443 | 0.101 | 0.403 | 0.105 | 0.566 | 0.086 | 0.473 | 0.097 |
| Averages of 30 Stations | | 0.514 | 0.073 | 0.461 | 0.079 | 0.426 | 0.081 | 0.561 | 0.071 | 0.487 | 0.076 |

Table 7. Sample equation for the 36-60 h (Period 2) rate of pan evaporation at Brannan Island, California for the 0000 GMT cycle.

| Predictor | Units | Smoothing (Points) | Forecast Projection (Hours) | Cumulative Reduction Of Variance | Coefficient |
|---|---|---|---|---|---|
| Regression Constant | -- | -- | -- | -- | -3.24 |
| 1. Daily Insolation | $w\ m^{-2}$ | -- | -- | .2997 | .000812 |
| 2. PE Mean Relative Humidity | % | 5 | 36 | .4429 | -.00341 |
| 3. PE 700-mb Temperature | $^{o}K$ | 5 | 36 | .4783 | .00894 |
| 4. PE Boundary Layer V | $m\ s^{-1}$ | 9 | 60 | .5035 | -.00656 |
| 5. PE 850-mb Height | m | 5 | 36 | .5197 | .000470 |
| 6. PE 850-mb Wind Speed | $m\ s^{-1}$ | 5 | 36 | .5357 | .00643 |
| 7. PE Layer 1 Relative Humidity | % | 5 | 36 | .5437 | .00218 |
| 8. PE 750-mb Vertical Velocity | $mb\ s^{-1}$ | 9 | 60 | .5514 | -8.10 |
| 9. PE Boundary Layer Wind Divergence | $s^{-1} \times 10^{-5}$ | 9 | 60 | .5571 | .0620 |
| 10. PE Boundary Layer Moisture Divergence | $s^{-1} \times 10^{-8}$ | 9 | 60 | .5636 | -.00616 |

Multiple Correlation Coefficient .7507
Standard Error of Estimate .0690